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S-IVB/V AUXILIARY PROPULSION SYSTEM 90-DAY RECYCLE CAPABILITY TEST REPORT, MODULE III

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MCDONNELL DOUGLAS ASTRONAUTICS COMPANY

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S-IVB/V AUXILIARY PROPULSION SYSTEM 90-DAY RECYCLE CAPABILITY TEST REPORT, MODULE III

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COORDINATED BY: W. L. BROWNING
PROJECT OFFICE-TEST-
HUNTINGTON BEACH DEVELOPMENT ENGINEERING
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PREPARED BY:
MCDONNELL DOUGLAS ASTRONAUTICS COMPANY
WESTERN DIVISION
SATURN S-IVB TEST PLANNING
AND EVALUATION COMMITTEE

PREPARED FOR:
NATIONAL AERONAUTICS AND
SPACE ADMINISTRATION
UNDER NASA CONTRACT NAS7-101
MODEL DSV-4B

A P O'neal

APPROVED BY: A. P. O'NEAL
HUNTINGTON BEACH DEVELOPMENT ENGINEERING DIRECTOR
SATURN/APOLLO & APOLLO APPLICATIONS PROGRAMS.

MCDONNELL DOUGLAS ASTRONAUTICS COMPANY
WESTERN DIVISION
5301 Bolsa Avenue, Huntington Beach, California 92647 (714) 897-031

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ABSTRACT

This report presents an evaluation of the Auxiliary Propulsion System 90-Day Recycle Capability Test, Module III that was conducted at the Sacramento Test Center from 2 December 1968 to 25 February 1969. The test was conducted to verify the capability of the Auxiliary Propulsion System propellant tanks and helium pressurization line to withstand simulated flight vibrations and shock loads while loaded with propellants.

This test program was conducted under National Aeronautics and Space Administration Contract NAS7-101, Change Orders 1671 and 1987.

DESCRIPTORS

Saturn S-IVB/V Stage	Auxiliary Propulsion System Module
Complex Gamma Test Facility	Sacramento Test Center
Complex Alpha Test Facility	

PREFACE

This report documents the evaluation of the Auxiliary Propulsion System 90-Day Recycle Capability Test on Module III as performed by MDAC-WD personnel at the Sacramento Test Center. The test was initiated on December 2, 1968, and completed February 25, 1969.

The purpose of the test was to demonstrate the capabilities of the S-IVB/V Auxiliary Propulsion System propellant tanks and helium pressurization line to withstand simulated flight vibration and shock loads while loaded with propellants.

This report, prepared under National Aeronautics and Space Administration Contract NAS7-101 (Change Orders 1671 and 1987), is issued in accordance with line item FQ-L-70 or report No. SM-41412, General Test Plan.

REVISION A

The failure analysis report that was prepared by the Bell Aerosystems Company on the defective bladder found in Module II has been published as Supplement I to this report.

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SECTION 1

INTRODUCTION

1. INTRODUCTION

This report presents the results and evaluation of the S-IVB/V Auxiliary Propulsion System vibration tests, module III, that were conducted at the Sacramento Test Center, Complex Gamma and Alpha test facilities.

The test program consisted of a series of vibration tests and a partial disassembly and inspection.

The information contained in the following sections documents and evaluates the test program that was initiated on 2 December 1968 and completed 25 February 1969. A test schedule is presented in figure 1-1.

1.1 Objective

The purpose of the test was to verify the capability of the APS module propellant tanks and helium pressurization line to withstand simulated flight vibration and shock loads while loaded with propellants.

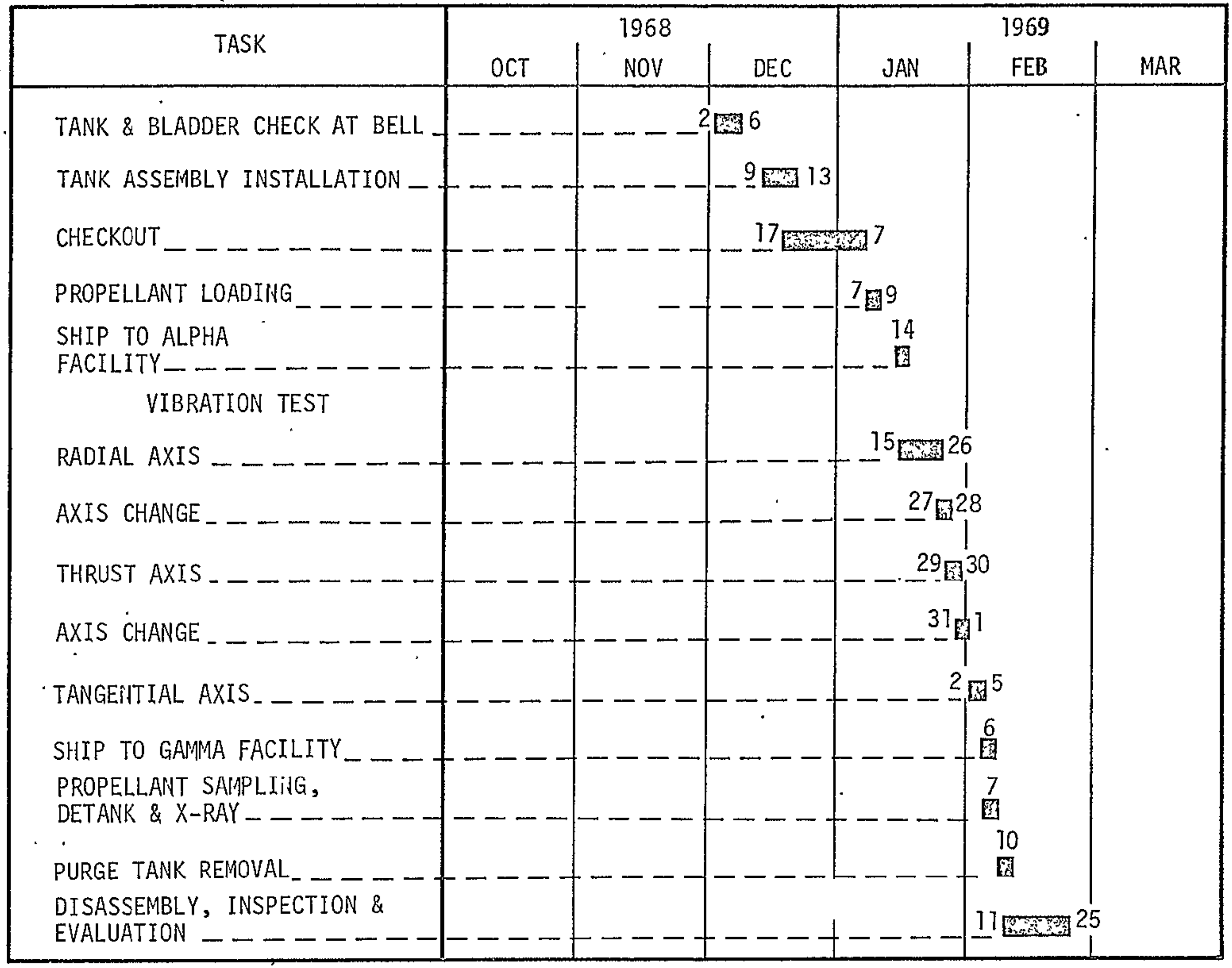


Figure 1-1. APS Module III Test Schedule

SECTION 2

SUMMARY

2. SUMMARY

The APS module III was subjected to vibration tests as presented in the S-IVB/V Auxiliary Propulsion System 90-day Recycle Capability Test Plan, DAC-56590E. The tests, conducted at the Sacramento Test Center, verified the capability of the APS module propellant tank assemblies and helium pressurization line to withstand simulated flight vibration and shock loads while loaded with propellants.

The APS module III consisted of the reworked module II. The rework consisted mainly of the replacement of the propellant tank assemblies and associated mounting brackets, and the helium pressurization line.

The following paragraphs describe the failures and anomalies that were noted during the tests.

A failure is defined as any discrepancy which could possibly cause loss of mission or delay of launch. An anomaly is defined as a discrepancy which is undesirable and not normal but which would not cause loss of mission or delay of launch.

2.1 Vibration Tests

The loaded APS module was installed in a vertical position and subjected to vibration and shock tests (as outlined in the Formal Qualification Test Procedure 1T31583) to simulate launch and flight vibration.

Results of the vibration tests indicate that no failures or anomalies occurred and the propellant bladder leakage experienced on modules I and II did not recur on this module.

The bladder leak noted in module II was thought to be linked to the protuberances found on the diffuser standpipe welds. Module III was subjected to special care to ensure the removal of all such weld defects. Since no bladder leaks occurred in module III, this supports the theory that the protuberances did cause the module II bladder leaks. However, folds occurring in the bladder could equally well result in a bladder rupture. At this point, the evidence is inconclusive.

The bladder vendor (Bell) has conducted an analysis of Module II bladder failure mode and its cause. This analysis is published in supplement I to this report

Since module III was the same module used for the module II vibration tests, it was significant in demonstrating the structural integrity of the system to endure two test programs.

2.2 Disassembly and Inspection

After completion of the vibration tests, the APS module propellant tank assemblies were removed and transported to the Complex Gamma Maintenance and Assembly Building for disassembly and inspection on 11 February 1969. No failures or anomalies were noted.

SECTION 3

AUXILIARY PROPULSION SYSTEM

3. AUXILIARY PROPULSION SYSTEM

The auxiliary propulsion system (APS) provides attitude control of the stage during all operational phases of S-IVB flight. The system also incorporates a propellant settling capability for damping mainstage propellant transients at the end of the first J-2 engine burn, and for J-2 engine restart after coast. Figure 3-1 is a schematic of the APS and instrumentation.

Subsystem components are contained in two separate modules placed 180 deg apart on the aft skirt. Each module (figure 3-2) contains hypergolic liquid bi-propellant engines, a positive expulsive propellant feed subsystem, and a helium pressurization subsystem. The fuel used by the APS is monomethylhydrazine (MMH) and the oxidizer is inhibited nitrogen tetroxide (N_2O_4). Propellants are stored in two separate tanks equipped with positive expulsive teflon bladders for propellant feed during zero g conditions.

Prior to launch countdown operations, each module is loaded with propellants through connections in the aft end of the module. During loading, the expulsion bladders must initially be in a fully expanded position against the tank wall. A differential pressure is maintained during the preparatory operations to assure that this condition is satisfied.

Propellant loading and recirculation are accomplished simultaneously. Propellant flow is established through the propellant control module transfer valve. The flow then divides, with a portion going to the propellant tank, and a portion circulating through the engine manifolding to eliminate gas from the system. After a full tank is achieved, propellant flow is continued for a short time to assure complete gas elimination. The propellant tank ullage is then established by of loading the required amount of propellant through the transfer valve.

Helium used for propellant expulsion is loaded into the module through a pneumatic service line connected to the stage through the fly-away stage umbilicals.

The APS modules are enabled in flight after the second stage retrorockets have been ignited. The APS provides stage roll control during S-IVB J-2 engine burn. Commands for operation of the APS engines are provided by the instrument unit. Output from a guidance platform indicating measured vehicle attitude is received in the instrument unit (IU), and a comparison is made with the desired or programmed attitude. If a deviation exists, the IU gives the required commands (via a control relay package) to the APS engine injector valves for thrust duration proportional to the magnitude of the deviation.

At J-2 engine cutoff, the APS pitch and yaw controls are activated, and all controls (pitch, yaw, and roll) remain active throughout the coast phase. At J-2 engine restart, the pitch and yaw modes are deactivated. The pitch and yaw modes are reactivated after J-2 engine second-burn cutoff to maintain 3 axes attitude control.

The APS ullage (propellant settling) engines (one in each module) are enabled during the J-2 engine first-burn cutoff transient to prevent undesirable stage propellant movement. Firing continues through the engine cutoff transient decay and the activation of the LH2 tank continuous propulsive vent system. The APS ullage engines are again fired at the end of orbital coast to provide propellant settling during J-2 engine restart.

3.1 Engine Systems

Three 150-lbf thrust attitude control engines and one 70-lbf thrust ullage engine are employed in each APS module. The 150-lbf thrust engines are manufactured by TRW Systems Group. The 70-lbf thrust engine was designed, developed, and manufactured under NASA contract by Rocketdyne Division of North American-Rockwell for the Gemini Program. The 150-lbf thrust engines employ quadruple injector valves for redundant valve action. The 70-lbf Gemini (ullage) engine employs single valves on both the fuel and oxidizer lines.

3.1.1 150-lbf Thrust Attitude Control Engines

Three 150-lbf thrust engines (figure 3-3) are employed in each APS module, and have quadruple propellant injector valves for redundancy. The thrust chamber is an integral part of the engine, and is composed of a combustion chamber, a nozzle throat section, and a nozzle expansion cone.

The injector consists of 12 pairs of unlike-on-unlike doublets arranged to minimize hot spots in the combustion chamber. The valve side of the injector is filled with a silver braze heat sink to reduce injector operating temperature.

The engine was qualified for a total pulse operation of 300 sec. During the 300-sec life requirement, the external wall temperature does not exceed 1,060 deg R, and the maximum valve body external temperature does not exceed 625 deg R. The maximum expected duty cycle requirements on the S-IVB/V is approximately 90 sec.

Engine propellant flow is controlled by a valve assembly which consists of eight solenoid valves arranged in two quad-redundant series-parallel valve arrangement to preclude any operational failure due to a single valve malfunction. A dual failure, such as two valves "failed open" in series or two valves "failed closed" in parallel, must occur to cause a failure.

The injector valves provide positive on/off control of propellant flow upon command from an external power source. Four valves, integral in an assembly, are capable of simultaneous operation and are synchronized to open or close within 3 ms of each other. The opening time for each valve assembly, defined as the time from initiation of open signal to fully open valve package, does not exceed 23 ms.

3.1.2 70-lbf Thrust Ullage Engine

Propellant settling is accomplished by a 70-lbf thrust film-cooled ullage engine (figure 3-4). Propellant flow to the engine is controlled by single solenoid valves: one for fuel and one for oxidizer. Engine operation has been qualified for continuous burn time of approximately 640 sec.

3.2 Propellant Feed System

The propellant feed system (figure 3-5) consists of separate fuel and oxidizer propellant tank assemblies, propellant control modules, and propellant manifolds for distribution of propellants to the engines. Filling of each tank assembly is accomplished through the outer (perforated) tube; the inner (solid wall) tube allows entrained gases in the bladder to be exhausted from the tank as the bladder is filled. Positive expulsion of propellants is accomplished by pressurizing the ullage space between the tank and the bladder.

3.2.1 Propellant Tanks

Each propellant tank (fuel and oxidizer) consists of an outer titanium pressure vessel (cylindrical shell with hemispherical ends of approximately 4,100 cu. in. capacity), an internal teflon bladder, and standpipe assembly (figure 3-5).

The bladder is fabricated of fluorinated ethylene propylene teflon laminated to polytetrafluoroethylene using a spray process resulting in a one-piece seamless unit with a nominal wall thickness of 6 mils. The bladder provides a separation membrane between the pressurization gas (ullage) and the propellant, and also provides a method of transferring propellant under zero g environment. The ullage space between the tank and the bladder is pressurized with helium gas to provide the expulsion pressure necessary for propellant flow.

A concentric tube standpipe assembly is located axially in the center of the tank assembly within the bladder. Propellant passes through perforations in the standpipe during expulsion as well as during filling operations. A vent tube is located within the standpipe assembly to allow removal of gas from inside the bladder.

3.2.2 Propellant Control Modules

The propellant control (figure 3-6) module provides for loading and recirculation of propellants and purging of the propellant systems.

The propellant transfer valve is a direct-operating, normally-closed solenoid valve. The transfer valve cannot be opened by application of power if the subsystem pressure exceeds external pressure by more than 10 psi, and the transfer valve will not close or remain closed if the external pressure exceeds subsystem pressure by more than 40 psi.

The propellant recirculation valve is a direct-acting, normally-closed solenoid valve with two independent poppets and seats. The two-poppet design isolates the engine recirculation line from the tank recirculation line, and all propellant flowing to the engine passes through a 10-micron nominal and 25-micron absolute rated filter.

3.2.3 Recirculation In-Line Filter

The filter assembly (figure 3-7) consists of a body with two in-line male tube fittings containing a filter element. The element is a welded assembly of a perforated support tube covered with corrugations of dutch twill weave wire cloth to provide an absolute filtering of particles greater than 25 microns.

Two filters are used in the fuel and oxidizer propellant recirculation lines to provide filtering of propellant or purge gas flowing through the propellant control module recirculation valve.

3.3 Helium Pressurization System

The helium pressurization system consists of two check valves in series, a helium storage tank, a helium pressure regulator assembly, two quadruple check valves, two filters, and two low pressure helium modules.

The helium storage tank stores helium at an initial pressure of 3,000 $\pm$200 psia. This pressure is reduced to 196 $\pm$3 psia for propellant tank ullage pressurization through a two-regulator module. These regulators are connected in series, and function by sensing the regulator downstream pressure.

Since a common pressurization subsystem is used, quadruple check valves are employed between the regulator and propellant tankage for added

assurance that hypergolics will not mix as the result of leaks or normal permeation. The low pressure helium modules provide ground venting capabilities of propellant tank ullage pressure, and a means of establishing pneumatic control of the expulsion bladders during loading and checkout. Command venting capabilities during flight are not provided, although the propellant tanks are protected from overpressurization by relief valves in the low pressure helium modules. All helium entering the regulated pressure area of the subsystem is filtered upstream of the regulators.

3.3.1 High Pressure Helium Tank

The helium tank is a welded titanium assembly consisting of a cylindrical center section and two hemispherical end domes, each containing a female tube fitting boss. The helium tank is a gas reservoir for the propellant positive-expulsion system on the S-IVB/V attitude control system.

3.3.2 Helium Pressure Regulator Module

Helium stored at 3,000 $\pm$200 psia in the high pressure helium tank is fed to a helium regulator module. The helium gas entering the module passes through an internal filter and then through two regulators in series, both of which sense downstream pressure. The first (or primary) regulator regulates the gas pressure to 196 $\pm$3 psig while the redundant secondary regulator regulates the gas pressure to 200 $\pm$3 psig. During normal operation, regulated pressure is maintained by the primary regulator. Should the primary regulator fail, the secondary regulator then begins operation. Each regulator is of fail-open design. Ambient pressure sensing ports, provided on both regulators, furnish the necessary ambient pressure references. Regulator performance is evaluated by pressure transducers installed immediately before and after the regulators. Regulated helium is fed through quadruple check valves and filters to the ullage area of the fuel and oxidizer tanks.

3.3.3 Quadruple Check Valves

Two sets of quadruple check valves are employed in the helium pressurization subsystem; one set in the fuel tank pressurization line, and the

other set in the oxidizer tank pressurization line. These check valves prevent contact of fuel and oxidizer vapors in the pressurization subsystem due to permeation through the bladders during normal operation or bladder leaks.

Each set of check valves consist of four check valves connected in a series-parallel arrangement and contained in one enclosure. Failure of a check valve set requires open-failure of two check valves in series or closed-failure of two check valves in parallel.

3.3.4 Low Pressure Helium Module

The low pressure helium module (figure 3-8) consists of a solenoid dump valve and a relief valve. Two low pressure modules are employed in the pressurization subsystem, one module connected to each propellant tank ullage volume. The solenoid dump valve is a normally-closed, direct-acting valve with a dual (redundant) coil. The valve performs no flight function, and is employed only to vent or pressurize the propellant tank ullage during ground servicing and checkout operations.

The purpose of the relief valve is to provide overpressurization protection of the propellant tankage during ground or flight operations.

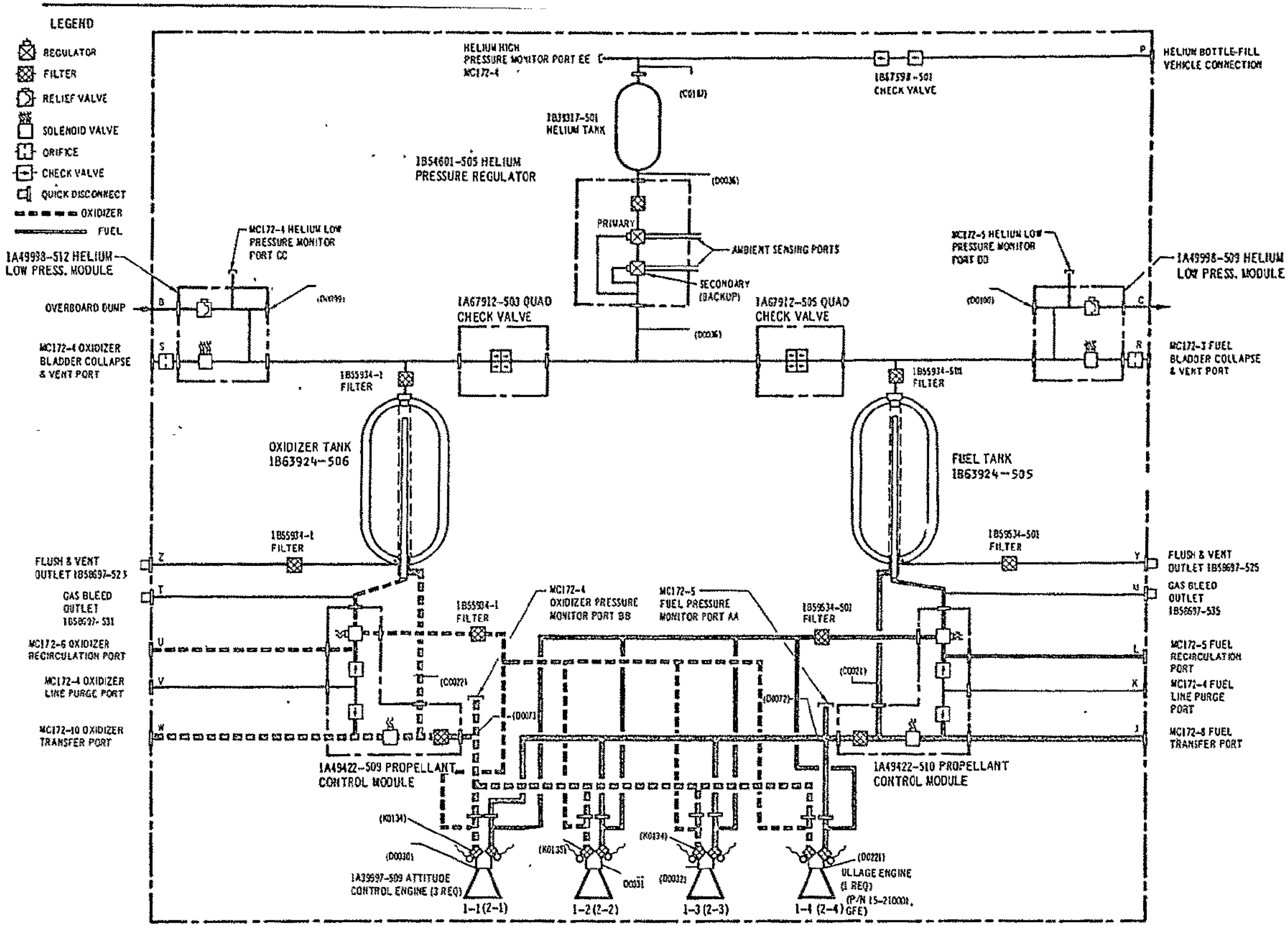


Figure 3-1. S-IVB/V Auxiliary Propulsion System and Instrumentation

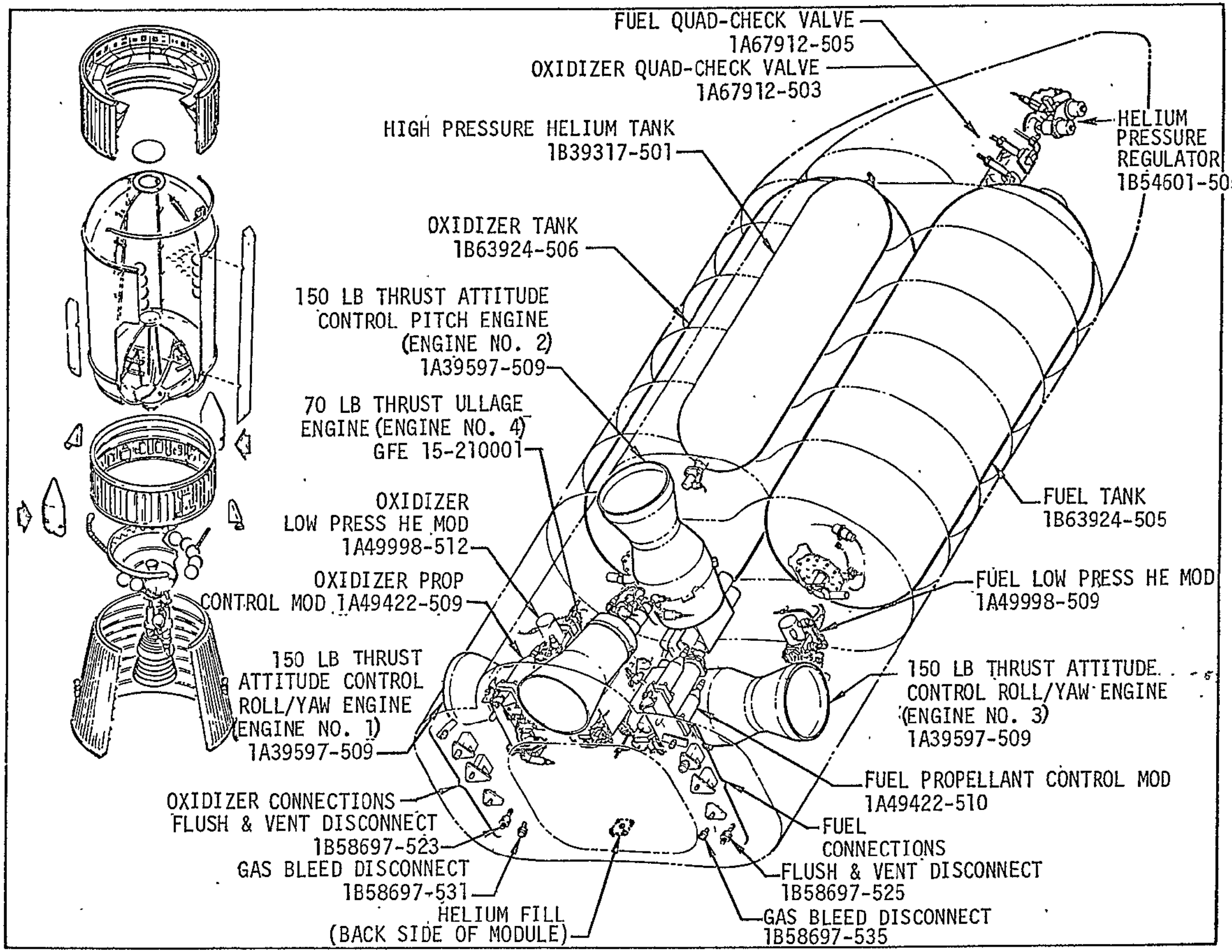


Figure 3-2. S-IVB/V Auxiliary Propulsion System Module

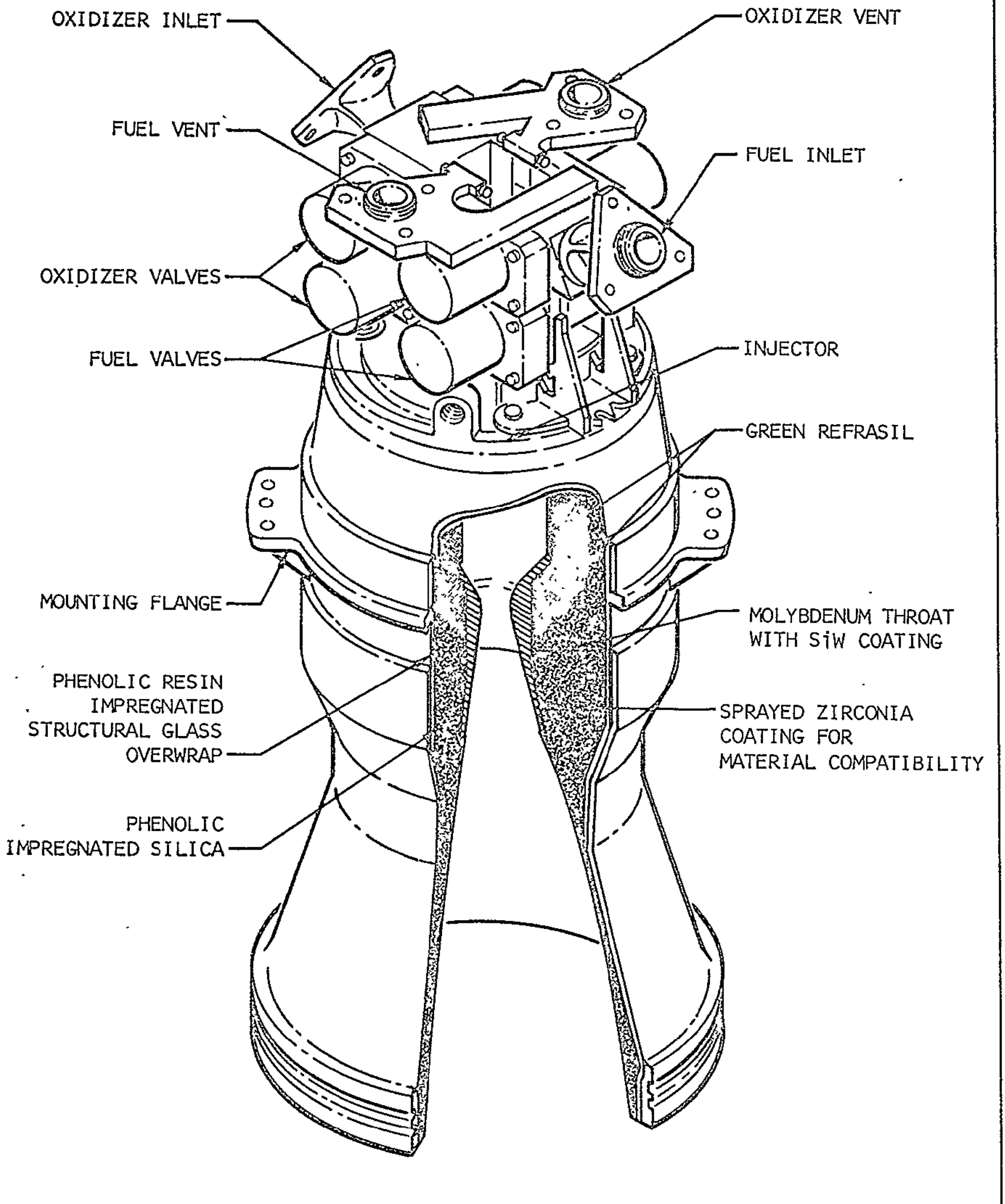


Figure 3-3. 150-lbf-Thrust Attitude Control Engine

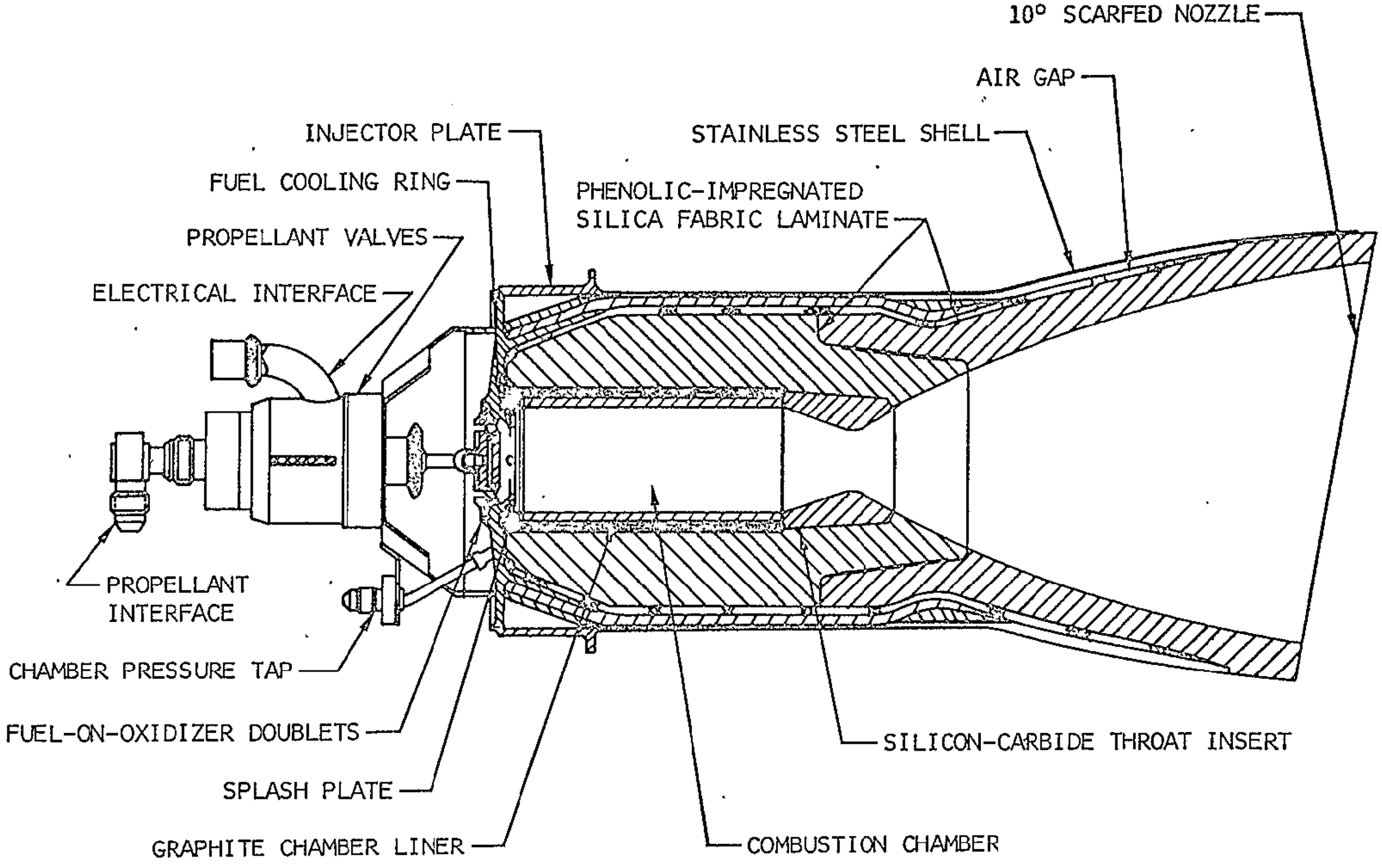


Figure 3-4. 70-lbf-Thrust Ullage Control Engine

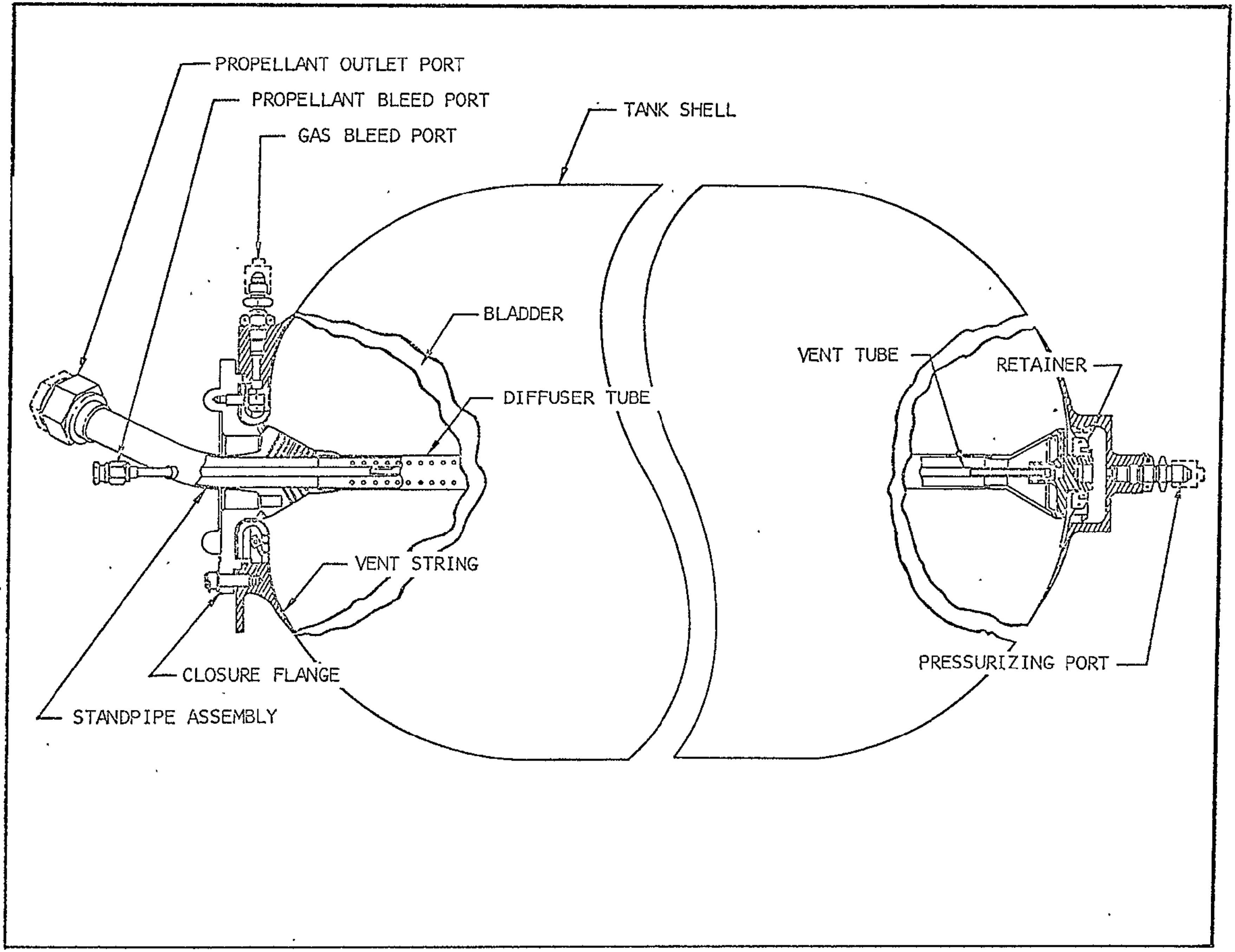


Figure 3-5. Positive Expulsion Propellant Tank

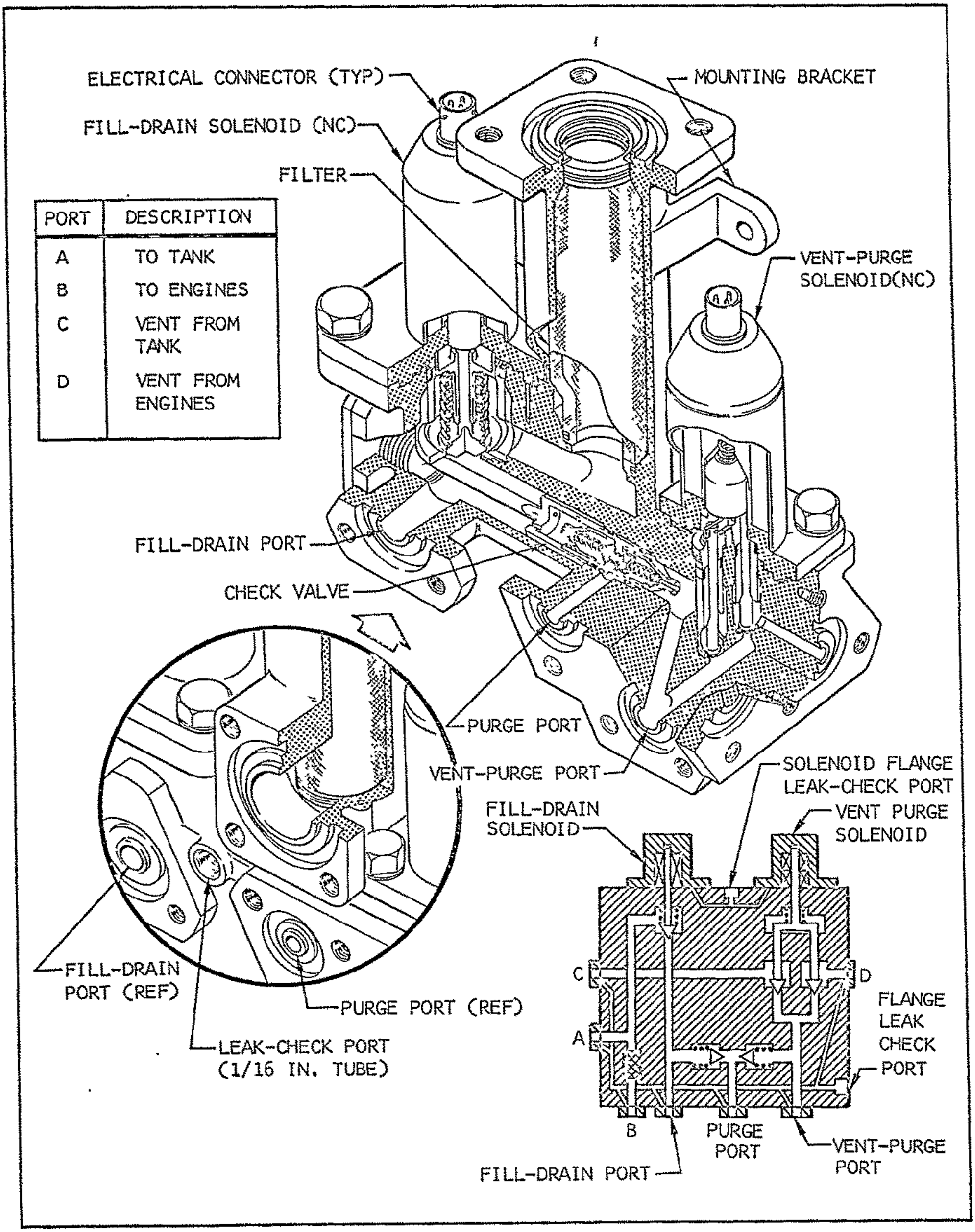


Figure 3-6. Propellant Control Module

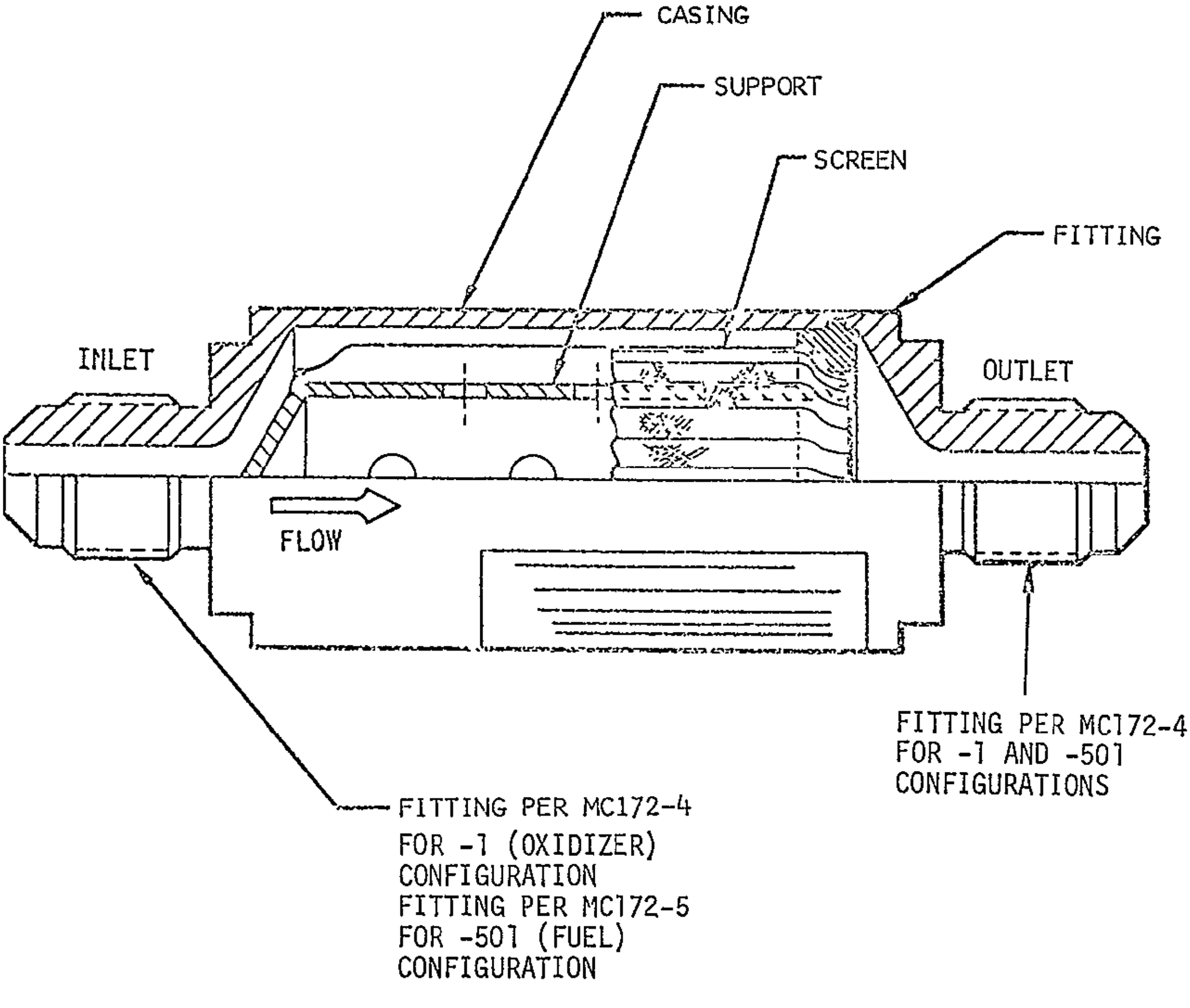


Figure 3-7. 25 Micron Recirculation In-Line Filter

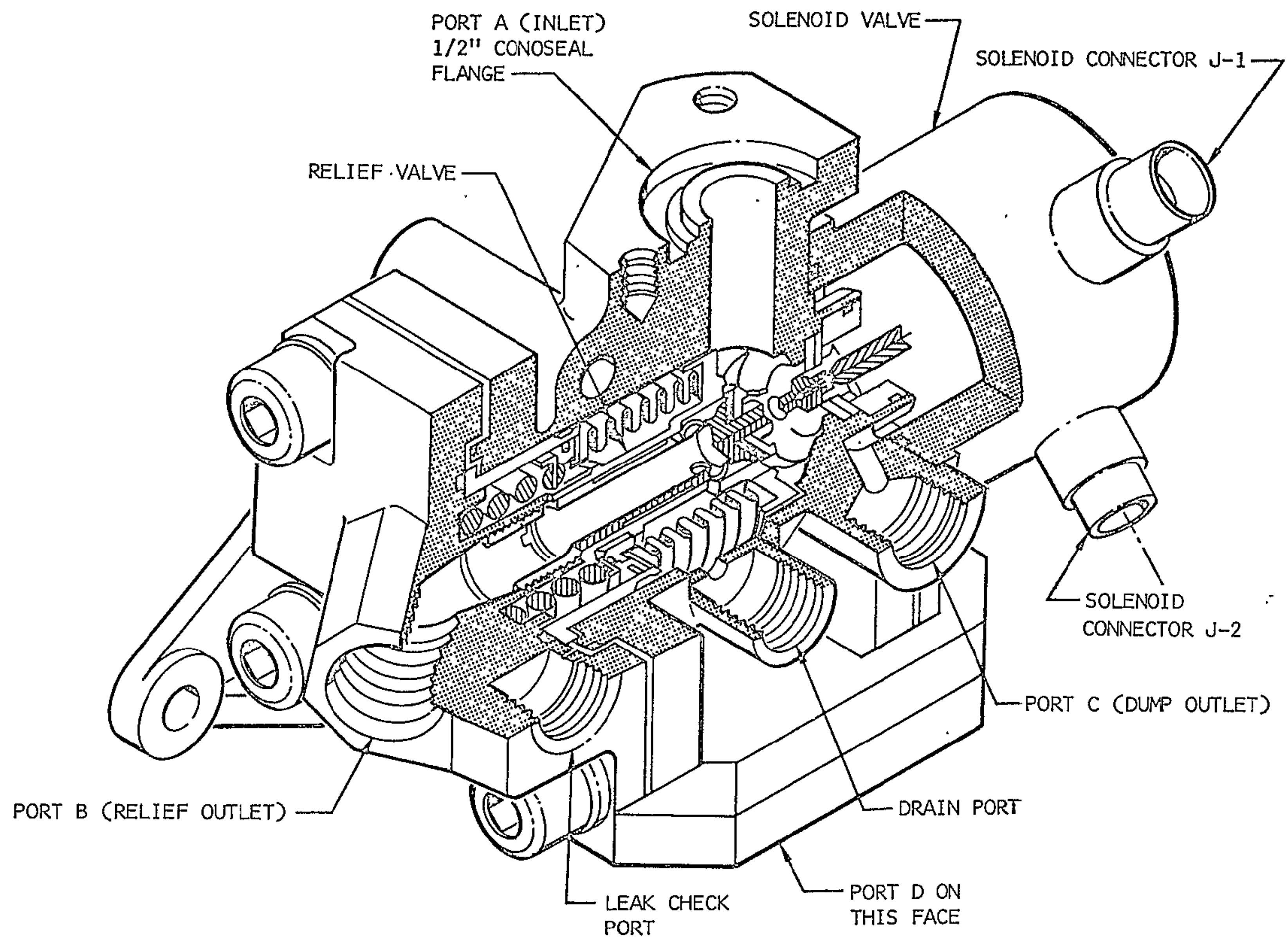


Figure 3-8. Low Pressure Helium Module

SECTION 4

TEST CONFIGURATION

4. TEST CONFIGURATION

4.1 APS Module III

The APS module (P/N 1A83918-535, S/N 507-2) used for the vibration tests was also used in the module II tests except for the propellant tank assemblies and pressurization lines which were replaced. APS module configuration at the completion of pretest checkout is shown in table 4-1. This table lists the major APS components, manufacturers, part numbers, and serial numbers.

4.2 Gamma Facility

The Gamma facility was utilized for pretest checkout, propellant loading, unloading, and disassembly.

4.3 Alpha Facility

The APS module III was transported to the Complex Alpha test facility for the vibration tests while loaded with propellants. The module was mated to a section of the aft skirt which was attached to a vibration fixture. The vibration fixture was attached to the shaker head of a C-210Y "MB" vibration exciter which was driven by two (2) "MB" model T999 power amplifiers. Because the test site is of open construction, an environmental control unit was required to maintain the module and propellant temperatures within the desired ranges. The environmental control unit was connected to the APS module by a flexible duct which supplied cool or warm air as required through the openings provided in the module fairing.

The electrical control panels located at Alpha Test Control Center provided for remote operation of the APS module and support equipment. Functions such as pressurizing, venting, and the ability to offload propellants in case of emergency were controlled manually. The test control center in addition to the meters on the operation console, also contained strip chart recorder channels for monitoring the critical redline parameters while the APS module was being vibrated.

A small portion of the Alpha Test Control Center instrumentation was used for the vibration test. The data recording equipment used included 10 strip chart channels, 3 dc amplifier channels, 3 signal condition channels, and 13 frequency modulation (FM) channels. The FM data was recorded on two 14-track tape recorders; one primary and one backup recorder. Two 14-track tape recorders were used by Engineering Laboratories and Services (EL&S) at the vibration site to record signals from twenty-two accelerometers and two strain gages. In addition, a time range generator, photo camera system, master calibration control console, closed circuit TV, and a video tape recorder were utilized.

TABLE 4-i AUXILIARY PROPULSION SYSTEM CONFIGURATION RECORD AT COMPLETION OF PRE-TEST CHECKOUT

Module P/N 1A83918-535 S/N 507-2

Component	Vendor	DACo P/N	S/N
Helium Check Valves	Sterer	1B67598-501	Upstream 150 Downstream 151
Helium Tank	DACo	1B39317-501	020
Helium Pressure Regulator	Fairchild-Stratos	1B54601-505	3825C740071
Quad Check Valve (Oxidizer)	Vinson	1A67912-503	1107
Quad Check Valve (Fuel)	Vinson	1A67912-505	1096
Ullage Filter (Oxidizer)	Western Filter	1B55934-1	1036314
Ullage Filter (Fuel)	Western Filter	1B55934-501	1036305
Helium Low Pressure Module (Oxidizer)	Vinson	1A49998-512	135G
Helium Low Pressure Module (Fuel)	Vinson	1A49998-509	117G
Propellant Tank (Oxidizer)	Bell Aerosystems	1B63924-506	037
Propellant Tank (Fuel)	Bell Aerosystems	1B63924-505	037
Propellant Control Module (Oxidizer)	Leonard	1A49422-509	0000072
Propellant Control Module (Fuel)	Leonard	1A49422-510	0000216
Engine Manifold Assembly (Oxidizer)	DACo	1B65684-1 1B59670-1	- -
Engine Manifold Assembly (Fuel)	DACo	1B51482-1 1B59679-1	- -
Engine 1	Tapco	1A39597-509	805
Engine 2	Tapco	1A39597-509	806
Engine 3	Tapco	1A39597-509	801
Engine 4	Rocketdyne	15-210001 *	4071851

* GFE

SECTION 5

TEST PROGRAM

5. TEST PROGRAM

5.1 General

The FQ-L-70 test program was revised to include a third vibration test program instead of two as was originally planned because of the failures experienced in the APS modules during the first two test programs.

The test program for module III included the rework of module II with new propellant tank assemblies, new propellant tank pressurization line and replacement of other miscellaneous hardware damaged during the testing of module II. The vibration test program and test requirements were the same as for module II with the exception of changing the sequence of vibration.

5.2 Propellant Tank Verification

The propellant tank bladder failure experienced on module II was believed to have been caused by a sharp protrusion on the upper tank diffuser standpipe weld. Therefore, to preclude a similar failure from occurring on module III, new propellant tank assemblies were installed in module II. A thorough inspection was made of the tank diffuser standpipe welds at the vendor prior to tank assembly installation. During this inspection, a sharp protrusion was found on the lower standpipe weld of the oxidizer tank and numerous small well-rounded inclusions were found on the upper welds of both the fuel and oxidizer tank diffuser standpipes. The small inclusions were within the Bell Aerosystem acceptable tolerance and were not removed; however, the sharp protrusion on the oxidizer standpipe lower weld was not acceptable and was removed prior to the installation of the bladder.

5.3 Pretest Checkout

Between 17 December 1968 and 7 January 1969, the APS module III was subjected to checkout operations at the Gamma test facility in accordance with standard checkout procedures. The following abnormalities were discovered during this checkout.

a. The inability to obtain a high differential pressure, current signature for engine No. 3 oxidizer valve 2 (downstream). Additional checkout indicated that valve 2 was closing 2 to 3 ms slower than valve 1 (upstream), making it impossible to achieve the high differential pressure condition for valve 2. This condition was identical to that found during the pretest checkout of module II and was acceptable for test.

b. A 6 sccm leak through the fuel propellant control module transfer check valve. The maximum allowable leakage through this valve is 5 sccm; however, because this module has been subjected to previous vibration testing and the check valve would never be used as flight hardware, the leak was accepted.

c. A slight leak was found at the fuel ullage filter-to-fuel quad check valve interface. This was corrected by replacing an "O" ring seal.

5.4 Propellant Loading

On 7 January 1969 the APS module was loaded with propellants in accordance with the standard loading procedure (H&CO 1B73217). The only anomaly noted was a decrease in propellant tank temperature. This was attributed to the test complex piping and valve complexes not being conditioned.

5.5 Pressurization

The following pressures were monitored during the vibration tests:

System	Parameter	Range (psia)
Low Pressure	Oxidizer Manifold and Ullage Pressure	203 - 222
Low Pressure	Fuel Manifold and Ullage Pressure	203 - 222
Low Pressure	Regulator Outlet Pressure	203 - 222
High Pressure	Helium Bottle Pressure	305 - 3,200

5.5.1 High Pressure System

The high pressure system was pressurized approximately 20 times between 14 January 1969 and 6 February 1969. Pressurization was always terminated below the helium bottle operating pressure limit of 3,200 psia.

During the pressurizations, the expected gas heating was observed. This heating usually peaked out at approximately 570 deg R. Most of the pressurizations were followed by a hold for temperature stabilization and a pressure decay check. No leaks were detected.

During the venting of the system, after the required testing (or trouble-shooting), the lowest temperature recorded was approximately 475 deg R.

5.5.2 Low Pressure System

The low pressure system was within the prescribed operating limits; however, an anomaly was noted during testing. The oxidizer manifold pressure exhibited pressure oscillations (ringing) at high vibration levels (figure 5-1). This ringing was also observed during the module I and module II testing and has been attributed to the low damping efficiency of the dashpot fluid used in the oxidizer manifold transducer.

5.6 Propellant Temperatures

The propellant temperature requirements during the vibration tests were as follows:

Parameter	Range (deg R)
Oxidizer Temperature	520 - 560
Fuel Temperature	520 - 560

5.6.1 Oxidizer Outlet Temperature

Temperature dropped below the minimum allowable temperature of 520 deg R on 14 and 15 January (figure 5-2). The oxidizer tank temperature was in the

acceptable region during this time, but the temperature sensing device was exposed to the ambient temperature and consequently gave a false indication.

For the remainder of the test the oxidizer temperature remained in the acceptable region (560 - 520 deg R).

5.6.2 Fuel Outlet Temperature

The temperature dropped below the minimum allowable two times during testing (figure 5-3). This was attributed to the temperature sensing device which was exposed to the ambient temperature resulting in a faulty bulk temperature indication.

5.7 Vibration Tests

5.7.1 APS Module Transportation to Alpha Complex

The APS module, loaded with propellants, was transported to the Alpha test site on 14 January. Acceleration measurements were made during hoisting and transportation at the input to the module in the thrust, radial, and tangential directions. During transportation, the maximum allowable dynamic load factor of 1.5 was exceeded during crane booming operations when the load factor reached 1.6. Levels generally remained below 0.2 g at a predominant frequency of less than 6 Hz except during the removal of the APS module from the test stand at Gamma when high frequency inputs reached a maximum of 1.85 g's. No damage was observed on the APS hoisting fixture or on the APS module.

5.7.2 General

The APS module was subjected to vibration and shock tests in the thrust, tangential, and radial axes per the levels and order presented in table 5-1. The vibration and shock requirements were as specified in Test Control Drawing 1T10923F "Formal Qualification Test, Saturn IVB/V Phase V APS Vibration." The module was tested in liftoff orientation with the propellant tanks loaded and the helium system pressurized to 3,000 $\pm$200 psi. The test specimen consisted of an APS module installed on a portion of aft skirt vehicle structure, which in turn was mounted on a rigid fixture.

Twenty-two accelerometers and two strain gages were used to monitor the dynamic input and response of the specimen (table 5-2). Accelerometer and strain gage locations are shown in figure 5-4. The strain gages were located on the oxidizer pressurization line at the location of the module I line failure; however, data were not obtained because of technical difficulties. The random vibration input was controlled from the average of the input acceleration levels at the lower right and upper right APS attach brackets, accelerometer locations 1 and 2, respectively. Sinusoidal vibration and shock tests were controlled at accelerometer location 1. In shock testing the control accelerometer signal was filtered with a 200 Hz low pass filter. Control signals in sinusoidal testing were filtered with a tracking filter.

Vibration and shock testing was per specification except for minor deviations considered acceptable by MSFC and MDAC dynamics representatives.

X-rays and full leak checks were performed before vibration testing. A leak check was made on the low pressure vent valves, relief valves, and the high pressure check valves after each mode (sinusoidal, random, and shock) in the three axes. In addition, a bladder leak check, a high pressure system leak (3000 psia) decay and a bubble soap leak (1500 psia) test, and a close visual inspection was accomplished after vibration tests in each of the three axes. These tests were repeated following the 30-sec radial random vibration test. Table 5-3 summarizes these tests.

The vibration and shock tests are described in the following paragraphs.

5.7.3 Radial Axis Tests

On 15 January, the APS was removed from the standby fixture and installed on the vibration fixture for testing in the radial axis. The pre-vibration test preparations were completed on 16 January. Photographs of the control and response accelerometers are shown in figure 5-5.

5.7.3.1 Sinusoidal Sweep Test

The sinusoidal phase of the radial axis vibration test was completed on 18 January. Replacement of a blown-out capacitor in the main shaker .

power amplifier delayed testing one day. Additional time was spent in checking out the difference in acceleration readings between the control accelerometers at locations 1 and 2. The final sweep was run with the level at accelerometer location 1 reduced to compensate for the higher levels at accelerometer location 2. Filtered acceleration data for this test are presented in figure 5-6. A potentiometer was used to measure double amplitude displacement at the input to the test backup structure. Displacement measurements are presented in figure 5-7.

5.7.3.2 Shock Test

The shock test was conducted on 19 January. The achieved shock pulses are shown in figure 5-8. Shock spectrum analyses of the control and several representative response accelerometers are shown in figure 5-9.

5.7.3.3 Low Level Random Vibration (Phase I)

Phase I low level random vibration testing was conducted on 19 January 1969. Vibration data are presented in figure 5-10.

5.7.3.4 High Level Random Vibration (Phase II)

Equalization for high level Phase II random vibration was started on 19 January but suspended several days due to problems with the equalizing equipment. On 23 January the Phase II random vibration test was completed. Acceleration data for this test are shown in figure 5-11.

5.7.3.5 High Level Random Vibration (Phase III)

High level Phase III random vibration equalization runs were started on 24 January but suspended one day due to burned out resistors in the main shaker power amplifier. New resistors arrived and the Phase III random vibration testing was completed on 26 January. Phase III random vibration control and response data are presented in figure 5-12.

5.7.4 Thrust Axis Tests

The APS was reinstalled on the vibration fixture and pretest preparations for thrust axis testing were completed on 29 January. Photographs of the control and response accelerometers are shown in figure 5-13.

5.7.4.1 Sinusoidal Sweep Test

Sinusoidal vibration testing was conducted on 30 January. The filtered control and response data are presented in figure 5-14.

5.7.4.2 Random Vibration Test

Random vibration testing was also conducted on 30 January. Acceleration data are shown in figure 5-15.

5.7.4.3 Shock Test

Shock testing was conducted on 30 January. The achieved shock pulses are presented in figure 5-16. Representative shock spectrum analyses of the control and several response accelerometers are shown in figure 5-17.

5.7.5 Tangential Axis Tests

The APS was reinstalled on the vibration fixture for tangential axis vibration and shock testing on 1 February. Photographs of the control and response accelerometers are shown in figure 5-18.

5.7.5.1 Sinusoidal Sweep Test

The sinusoidal sweep test was conducted on 2 February. Filtered acceleration data for this test are presented in figure 5-19.

5.7.5.2 Random Vibration Test

Random vibration testing started on 2 February but was delayed several days due to equalization difficulties. An attempt was made on 4 February to equalize with some new averaging equipment but no improvement was noted. This equipment was removed from the system and the two controls were averaged manually. Random vibration testing was conducted on 5 February. Control and response data are presented in figure 5-22.

5.7.5.3 Shock Test

On 4 February, the shock test was conducted. The achieved shock pulses are presented in figure 5-20. Representative shock spectrum analyses of the control and several response accelerometers are shown in figure 5-21.

5.7.6 APS Module Transportation to Complex Gamma

The APS module was transferred from Alpha to Gamma on 6 February. The module remained within the maximum dynamic load factor of 1.5 except during booming down operations to clear overhead wires when the blast cylinder, in which the module is housed, touched the ground. At this time a shock was measured in the thrust direction, which reached a magnitude of 0.8 g in a rise time of 220 ms, and set up complex oscillations in the frequency ranges of 20, 12.5, 1.3, and 0.6 Hz. Peak response in the thrust direction was 1.4 g's. Approximately 650 ms later, an input pulse of 0.8 g, with a rise time of 200 ms, was measured in the tangential direction. Subsequent oscillations of 20, 1.25 and 0.7 Hz were experienced in the tangential axis and a peak response of 1.8 g's was measured. A third impact was measured in the radial direction, 1.2 sec after the initial shock in the thrust axis. The input was of short duration and set up radial axis oscillation at a predominant frequency of 20 Hz. The maximum response level reached was 3.4 g's. Throughout road transportation, the acceleration of the APS module was generally below 0.2 g and at a fundamental frequency below 1 Hz. During placement of the APS module into cell No. 3 at Gamma, 1/2 Hz oscillations of 0.8 g were recorded in the thrust axis. No damage occurred to the APS hoisting fixture or the APS module.

5.8 Propellant Unloading, System Purge, Disassembly and Inspection of Propellant Tanks

Propellant unloading was performed on 7 February per MDC H&CO 1B73218, Task 10. Prior to unloading, X-ray photographs were taken of both propellant tanks to show final levels, and 1,000 cc of propellant were removed from each APS tank for analysis. The fuel analysis indicated that transmittancy did not meet the 90 percent minimum specified in MIL-P-27404 (the sample value was 83 percent). The oxidizer sample was satisfactory. Propellant unloading and post-unloading purges were carried out with no difficulty whatever, after which the APS was depressurized to blanket pressures and the tank bladders were pressurized to 9 psid positive pressure. On 10 February, it was not possible to re-establish the 9 psid differential pressure across the fuel bladder and a possible bladder failure was suspected. The propellant tanks were removed from the

APS for a detailed leak test, and disassembly and inspection. The leak test and visual inspection following disassembly verified the bladder was in excellent condition. The suspected bladder leak was caused by the insufficient time allowed for the bladder to expand against the tank walls. A detailed description of this disassembly and inspection can be found in DAC-61240, S-IVB/V Auxiliary Propulsion System Phase V-3 Post Test Disassembly and Inspection 14 Day Report.

5.9 Conclusion

All of the test objectives were met and no failure or anomalies were noted during the vibration testing. Since module III was the same module used for the module II vibration test, with the exception of the tank assemblies, mounting brackets and pressurization line, it was significant in demonstrating the structural integrity of the system to endure two test programs. The bladder leak found in module II was thought to be linked to the protuberances found on the diffuser standpipe welds. The module III tank assemblies were subjected to special care to ensure the removal of all such protuberances. Since no bladder leaks occurred in module III, this supports the theory that the protuberances did cause the module II bladder leaks. However, folds occurring in the bladder could equally well result in a bladder rupture. At this point, the evidence is inconclusive.

The bladder vendor (Bell) has conducted an analysis of Module I bladder failure mode and its cause. This analysis is published in supplement I to this report.

TABLE 5-1 (Sheet 1 of 2)
VIBRATION REQUIREMENTS

RADIAL AXI

SINE

3 oct/min (upsweep only)

1.5 to 2.5 Hz at 0.04 G, zero to peak
2.5 to 3.5 Hz at 0.125-inch D.A. Displacement
3.5 to 20 Hz at 0.08 G, zero to peak

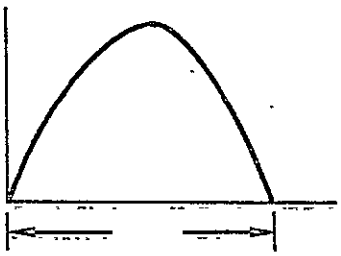
SHOCK

(3 per axis)

15 G's

Peak

(half-sine wave)



5±1 Time (milliseconds)

RANDOM

PHASE I	(2 minutes)
20 - 85 Hz	0.025 g^2/Hz
85 - 280 Hz	+6.5 dB/octave
280 - 1,000 Hz	0.31 g^2/Hz
1,000 - 2,000 Hz	-12 dB/octave
PHASE II	(30 seconds)
20 - 170 Hz	0.1 g^2/Hz
170 - 280 Hz	6.5 dB/octave
280 - 1,000 Hz	0.31 g^2/Hz
1,000 - 2,000 Hz	-12 dB/octave
PHASE III	(55 seconds)
20 - 170 Hz	0.1 g^2/Hz
170 - 280 Hz	6.5 dB/octave
280 - 1,000 Hz	0.31 g^2/Hz
,000 - 2,000 Hz	-12 dB/octave

TABLE 5-1 (Sheet 2 of 2)
VIBRATION REQUIREMENTS

THRUST AXIS

SINE

1 oct/min 3 - 7 Hz; 3 oct/min 7 - 20 Hz
(upsweep only)

3 to 4 Hz at 0.24 inch D.A. Displacement
4 to 7 Hz at 0.2 g's peak
7 to 20 Hz at 0.1 g's peak

RANDOM

(3 minutes)

20 - 30 cps at +6 dB/octave
30 - 100 cps at .01 g^2/cps
100 - 200 cps at +6 dB/octave
200 - 1,000 cps at .05 g^2/cps
1,000 - 2,000 cps at -3 dB/octave

SHOCK

(Same as for radial axis)

TANGENTIAL AXIS

SINE

(Same as for thrust axis)

SHOCK

(Same as for radial axis)

TABLE 5-2
ACCELEROMETER AND STRAIN GAGE
LOCATIONS AND ORIENTATIONS

	LOCATION	ORIENTATION		
		Thrust	Tangential	Radial
1	Control-Lower Right APS Attach Bracket	Thrust	Tangential	Radial
2	Alt. Control-Upper Right APS Attach Bracket	Thrust	Tangential	Radial
3	Quad. Check Valve and He. Press. Regulator-Input	Thrust	Tangential	Radial
4	Shaker Head	Thrust	Tangential	Radial
5	Quad. Check Valve-Response	Thrust	Tangential	Radial
6	Fuel Tank-Aft-Response	Thrust	Tangential	Radial
7	Oxidizer Tank Aft Response	Thrust	Tangential	Radial
8	Ox. Prop. Control Mod L-5 Input	Radial	Radial	Radial
9	Fuel Low Press. He. Mod. (Ullage Vent Valve L04) Response	Thrust	Tangential	Radial
10	Engine No. 4 (Ullage) Input	Thrust	Tangential	Radial
11s	Oxidizer Tank Press. Line Quad. Check Valve End-Strain Gauge	-	-	-
12s	Oxidizer Tank Press. Line Quad. Check Valve End-Strain Gauge	-	-	-
13	Lower Left APS Attach Bracket	Thrust	Tangential	Radial
14	Upper Left APS Attach Bracket	Thrust	Tangential	Radial
15	APS Module-Center Response	Thrust	Tangential	Radial
16	Fuel Tank-Forward Response	Thrust	Thrust	Thrust
17	APS Module-Forward Response	Thrust	Tangential	Radial
18	Ox. Prop. Control Mod. L-5 Input	Tangential	Tangential	Tangential
19	Oxidizer Tank-Forward Response	Thrust	Thrust	Thrust
20	Oxidizer Tank-Forward Response	Radial	Radial	Radial
21	Oxidizer Tank-Forward Response	Tangential	Tangential	Tangential
22	Oxidizer Tank-Aft Input	Thrust	Tangential	Radial
23	Fuel Tank-Forward Response	Radial	Tangential	Radial
24	Amplifier-Engine Press. Transducer-Response	Thrust	Tangential	Radial

Left and right are as viewed from outside vehicle.

s - Strain Gauges

TABLE 5-3 PRETEST CHECKOUT SUMMARY

1.0 HIGH PRESSURE HELIUM SYSTEM CHECKOUT

Test	Test Procedure	Allowable Limits	Test Results	Comments
Helium Check Valves Functional Check and Preliminary Leak Check (4.2.1)	Pressurize APS to 1500 psig and monitor regulator outlet pressure. Leak check all connections in He supply system for leaks.	Regulator Outlet Press. 188-201 psig. No leakage allowed.	196 psig	Satisfactory
Helium Regulator Functional Check (4.2.1)	Increase the He supply to 3100 psig in 500 psig steps. At each step create a demand on the regulator and check lock-up pressure.	Regulator Lock Press. shall be 188-201 psig and be consistent within ± 1 psig.	196 psig	Satisfactory
Helium System High Pressure Leak Check (4.2.2)	Pressurize APS to 3150 psig and check for reverse flow through high pressure check valves, check for leakage at both high pressure transducer leak detection ports, and both regulator reference ports. Allow APS pressure to stabilize and measure pressure decay for 1 hour.			

System		Limits	Result	Comments
Port P	H/P	51 SCCM	0	Satisfactory
	L/P	51 SCCM	0.1	Satisfactory
Redundant He Check Valve	H/P	51 SCCM	0	Satisfactory
	L/P	51 SCCM	0	Satisfactory
He. Press. Xducer #1		1.8 SCCM	0	Satisfactory
He. Press. Xducer #2		1.8 SCCM	- - - -	Not Installed
Reg. Ref. Port A		1 SCCM	0	Satisfactory
Reg. Ref. Port B		1 SCCM	0	Satisfactory
He Tank		11 psid/hr	1 psid	Satisfactory

The numbers shown in parenthesis are the applicable paragraphs in MDAC H&CO 1E73220.

TABLE 5-3 PRETEST CHECKOUT SUMMARY (CONT'D)

2.0 PROPELLANT AND PRESSURIZATION SYSTEM LEAK AND FUNCTIONAL CHECKOUT

Test	Test Procedure	System	Allowable Limits	Test Results	Comments
Critical Valve Functionals (4.3.2)	Pressurize APS to 40 ± 5 psig and individually cycle open then closed both low pressure helium module vent valves utilizing both coils. Monitor vent ports for venting.		Venting during all cycles.	Venting noted.	Satisfactory
Propellant Control Module Check Valves Leak Check (4.3.3)	Pressurize the check valve outlets to 23 ± 3 psig and measure reverse leakage	System	Limits	Results	Comments
		Oxidizer	5 SCCM	0 SCCM	Satisfactory
		Fuel	5 SCCM	6 SCCM	*
Quad Check Valve Cracking Pressure Test (4.3.4)		System	Limits	Results	Comments
A. Cracking Pressure	Pressurize APS to 25 psig and compare check valves upstream and downstream pressure.	A Oxidizer	2-5 psid	3.25 psid	Satisfactory
		A Fuel	2-5 psid	3.75 psid	Satisfactory
		—	—	—	—
B. Low Pressure Leak Check	Pressurize the check valve outlets to 5 ± 1/2 psig and measure reverse leakage.	B Oxidizer	3 SCCM	0.5 SCCM	Satisfactory
		B Fuel	Combined	Combined	Satisfactory

The numbers shown in parenthesis are the applicable paragraph in MDAC H&CO 1B73220

* The out-of-tolerance condition was accepted as satisfactory for this test.

TABLE 5-3 PRETEST CHECKOUT SUMMARY (CONT'D)

2.0 PROPELLANT AND PRESSURIZATION SYSTEM LEAK AND FUNCTIONAL CHECKOUT (CONT'D)

Test	Test Procedure	Allowable Limits	Test Results	Comments
C. High Pressure Leak Check	Pressurize the check valve outlets to 210 ± 5 psig and measure reverse leakage.	3 SCCM Maximum (Combined)	0.5 SCCM (Combined)	Satisfactory

Test	Test Procedure	Test	Limits	Valve	Results	Comments
Low Pressure Helium Module Relief Valves Check (4.3.6)	Pressurize each valve until relief valve cracks, decrease pressure to 220 ± 2 psig and measure leakage, decrease pressure to 195 ± 2 psig and measure leakage.	Cracking Pressure	325-350 psig	Oxid	337-338	Satisfactory
				Fuel	338-337	Satisfactory
		Leakage	1.0 SCCM	Oxid	0	Satisfactory
			1.0 SCCM	Fuel	0	Satisfactory

Test	Test Procedure	Allowable Limits	Test Results	Comments
Pressure Regulator Functional Test (4.3.6)				
A. Primary Regulator	Pressurize APS to 1500 ± 50 psig with both regulator reference pressures at ambient. Cycle each vent and measure flow rate and flow and lock-up pressure.	3.23-17.95 CFM	7.5 CFM	Satisfactory
		Flow Pressure 185-197 psig	189 psig	Satisfactory
		Lock Up Pressure 188-201 psig	196 psig	Satisfactory
B. Secondary Regulator	Same as A except with primary regulator disabled.	3.23-17.95 CFM	7.5 CFM	Satisfactory
		Flow Pressure 189-205 psig	197	Satisfactory
		Lock Up Pressure 192-205 psig	201	Satisfactory

The numbers shown in parenthesis are the applicable paragraph in MDAC H&CO 1B73220

TABLE 5-3 PRETEST CHECKOUT SUMMARY (CONT'D)

2.0 PROPELLANT AND PRESSURIZATION SYSTEM LEAK AND FUNCTIONAL CHECKOUT (CONT'D)

Test	Test Procedure	Allowable Limits	Test Results	Comments
Engine Valves Functional Check (4.3.8)	Pressurize APS to 208 psig and energize valves. Measure solenoid current and valve actuation times.	Attitude Control Engines		
		Current: 1.3 amp maximum	0.88-0.98 amp	Satisfactory
		Poppet Travel: 1-4 ms.	1.5-2.5 ms.	Satisfactory
		Syncronization: 3 ms maximum	* 0-3 ms.	Satisfactory
		Actuation Time Hi P 23 ms maximum	* 14.5-18.5 ms.	Satisfactory
		Actuation Time Low P 17 ms maximum.	8-12.5 ms.	Satisfactory
		Ullage Control Engine		
		Current: 1.0 amp maximum	0.62-0.67	Satisfactory
		Poppet Travel: 1-3 ms maximum	1.5 ms.	Satisfactory
		Actuation Time: 21 ms maximum	12.5-14.5 ms.	Satisfactory

The numbers shown in parenthesis are the applicable paragraph in MDAC H&CO 1B73220
*As covered in the report text, it was not possible to obtain a high differential pressure valve signature for valve 2 of engine 3. This condition was accepted for this test. Ref. A45-KCDC-ROD-68133.

TABLE 5-3 PRETEST CHECKOUT SUMMARY (CONT'D)

2.0 PROPELLANT AND PRESSURIZATION SYSTEM LEAK AND FUNCTIONAL CHECKOUT (CONT'D)

Test	Test Procedure	Valve	Engine	Limits	Rate	Comments
Engine Valve Leak Checks (4.3.10)	Pressurize APS to 210 ± 10 psig and measure engine valve leakage.	All Valves	1	1 SCCM	0	Satisfactory
			2	1 SCCM	0.02 SCCM	Satisfactory
			3	1 SCCM	0	Satisfactory
			4	1 SCCM	0.06 SCCM	Satisfactory
		A & C	1	1 SCCM	0	Satisfactory
			2	1 SCCM	0	Satisfactory
			3	1 SCCM	0	Satisfactory
		B & D	1	1 SCCM	0.04 SCCM	Satisfactory
			2	1 SCCM	0.02 SCCM	Satisfactory
			3	1 SCCM	0	Satisfactory
		1 & 3	1	1 SCCM	0.1 SCCM	Satisfactory
			2	1 SCCM	0.52 SCCM	Satisfactory
			3	1 SCCM	0	Satisfactory
		2 & 4	1	1 SCCM	0.05 SCCM	Satisfactory
			2	1 SCCM	0.45 SCCM	Satisfactory
			3	1 SCCM	0	Satisfactory
Engine Combustion Chamber Leak Checks (4.3.9)	Pressurize combustion chambers to 85 psig (throat plugs installed) and measure pressure decay rate. Check for external leaks.		Engine	Limits	Rate	Comments
			1	1 psid/min	0.04 psid	Satisfactory
			2	1 psid/min	0	Satisfactory
			3	1 psid/min	0	Satisfactory
			4	*	0	Satisfactory

*No limit established. Data recorded for record only.

The numbers shown in parenthesis are the applicable paragraph in MDAC H&CO 1B73220

TABLE 5-3 PRETEST CHECKOUT SUMMARY (CONT'D)

2.0 PROPELLANT AND PRESSURIZATION SYSTEM LEAK AND FUNCTIONAL CHECKOUT (CONT'D)

Test	Test Procedure	Component	Limits	Results	Comments
Full Operating Pressure Leak Check (4.3.11)	Pressurize APS to 1500 ± 50 psig and monitor APS system for pressure decay. Check all components and connections for external leakage.	Helium Tank	50 psid	0 psid	
		Oxidizer System	3 psid	0 psig	
		Oxidizer Ullage	3 psid	2 psid	
		Fuel System	3 psid	1 psid	
		Fuel Ullage	3 psid	1 psid	
		Oxid Transfer Port	30 SCCH	0.3 SCCH	
		Oxid Recirc. Port	30 SCCH	0.1 SCCH	
		Oxid Vent Port	240 SCCH	0	
		Oxid Relief Port	60 SCCH	0.2 SCCH	
		Fuel Transfer Port	30 SCCH	1.1 SCCH	
		Fuel Recirc. Port	30 SCCH	0.2 SCCH	
		Fuel Vent Port	240 SCCH	0	
		Fuel Relief Port	60 SCCH	0.2 SCCH	
		Reg Primary Ref.	1 SCCH	0.3 SCCH	
		Reg Secondary Ref.	1 SCCH	0.1 SCCH	
		Helium Fill Port	51 SCCH	0.2 SCCH	
		Oxid Gas Bleed	6 SCCH	0	
		Fuel Gas Bleed	6 SCCH		

The numbers shown in parenthesis are the applicable paragraph in MDAC H&CO 1B73220

TABLE 5-3 PRETEST CHECKOUT SUMMARY (CONT'D)

2.0 PROPELLANT AND PRESSURIZATION SYSTEM LEAK AND FUNCTIONAL CHECKOUT (CONT'D)

Test	Test Procedure	Component	Limits	Results	Comments
System and Ullage Valves, Low Pressure Leak Check (4.3.12)	Pressurize APS to 23 ± 3 psig and measure leakage through indicated ports.	Oxid Transfer Port	0.5 SCCM	0	Satisfactory
		Oxid Recirc. Port	0.5 SCCM	0	Satisfactory
		Fuel Transfer Port	0.5 SCCM	0	Satisfactory
		Fuel Recirc. Port	0.5 SCCM	0	Satisfactory
		Eng. 1 Valves	1 SCCM	0	Satisfactory
		Eng. 2 Valves	1 SCCM	0	Satisfactory
		Eng. 3 Valves	1 SCCM	0	Satisfactory
		Eng. 4 Valves	1 SCCM	0	Satisfactory
		Oxid Vent Port	1 SCCM	0	Satisfactory
		Oxid Relief Port	4 SCCM	0.04 SCCM	Satisfactory
		Fuel Vent Port	1 SCCM	0	Satisfactory
		Fuel Relief Port	4 SCCM	0	Satisfactory
		Oxid Gas Bleed Port	0.1 SCCM	0	Satisfactory
		Fuel Gas Bleed Port	0.1 SCCM	0	Satisfactory

The numbers shown in parenthesis are the applicable paragraph in MDAC H&CO 1B73220

TABLE 5-3 PRETEST CHECKOUT SUMMARY (CONT'D)

3.0 PROPELLANT TANK CHECKOUT

Item	Procedure	Spec.	Result	Comments	Ref. *
Fuel Tank					
a. Attachment Joint Leakage	Connect tank to APS systems. Position bladder against inner wall. Pressurize ullage and propellant system to 155±10 psia. Check external connections with bubble soap and monitor pressure decay for 15 min.	5 psid decay, max.	Less than 5 psid.	Satisfactory	4.2.4
b. Bladder Leakage	Reposition bladder against inner tank wall. With ullage side vented to ambient, pressurize propellant side of bladder to 24±1 psia. Monitor leakage at ullage drain fitting for 15 min on water manometer.	180 scc/30 min. (helium)	15 scc/15 min.	Satisfactory	4.2.6
c. Pre-Load Purge	Purge system with 24±1 psia GN2 until effluent gas contains less than 50 ppm moisture.	32 ppm, max.	42 ppm.	Satisfactory	4.2.7
Oxid Tank					
a. Attachment Joint Leakage	Connect tank to APS systems. Position bladder against inner wall. Pressurize ullage and propellant system to 155±10 psia. Check external connections with bubble soap and monitor pressure decay for 15 min.	5 psid decay, max.	2.5 decay, max.	Satisfactory	4.3.4
b. Bladder Leakage	Reposition bladder against inner tank wall. With ullage side vented to ambient, pressurize propellant side of bladder to 24±1 psia. Monitor leakage at ullage drain fitting for 15 min on water manometer.	180 ssc/30 min. (helium)	15 scc/15 min.	Satisfactory	4.3.6

* Indicates applicable paragraph in Douglas Drawing 1B70153

TABLE 5-3 PRETEST CHECKOUT SUMMARY (CONT'D)

3.0 PROPELLANT TANK CHECKOUT (CONT'D)

Item	Procedure	Spec.	Result	Comments	Ref. *
Oxid Tank (cont)					
c. Pre-Load Purge	Purge system with 24±1 psia GN2 until effluent gas contains less than 50 ppm moisture.	50 ppm, max.	30 ppm.	Satisfactory	4.3.7

* Indicates applicable paragraph in Douglas Drawing 1B70153

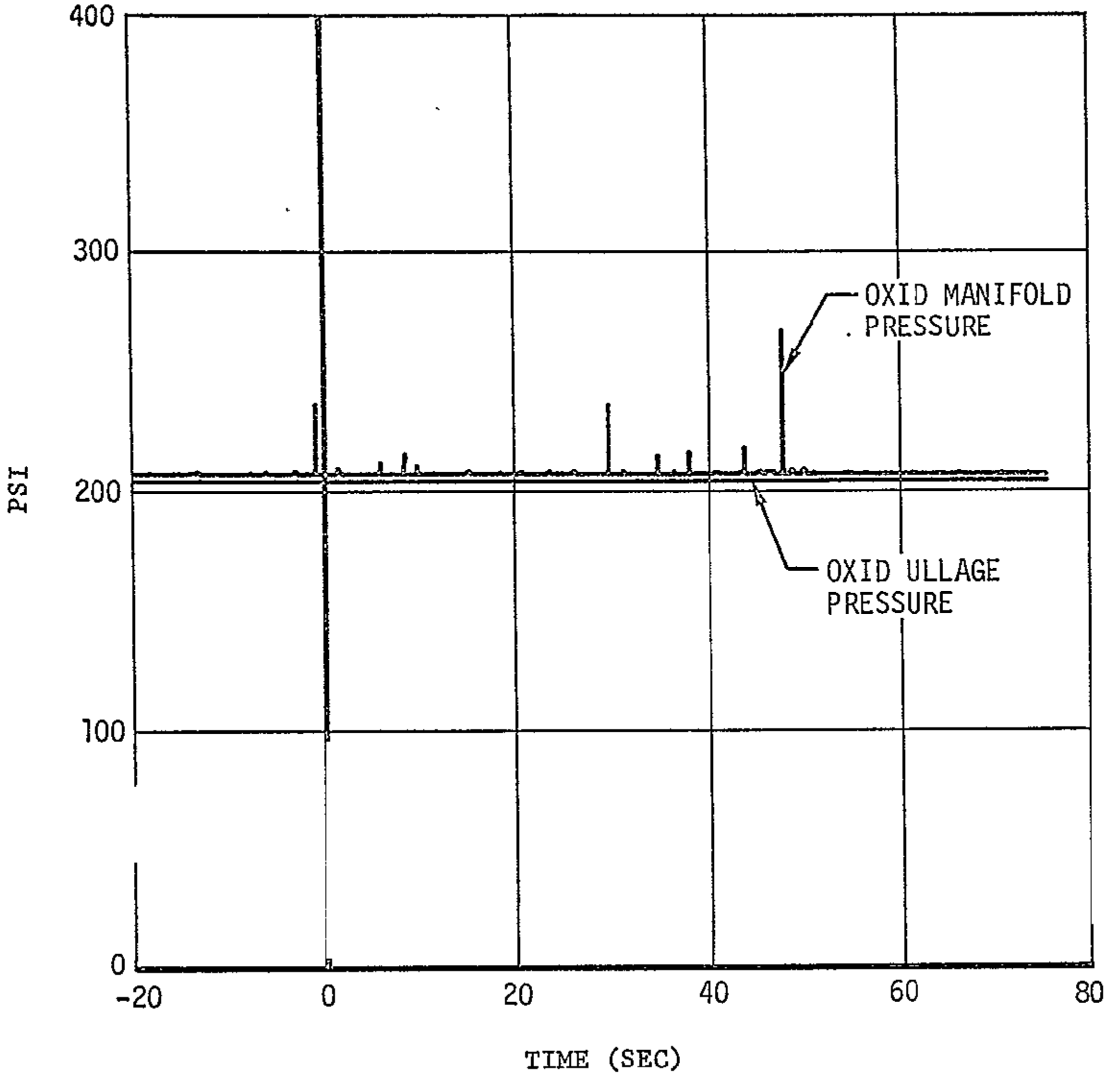


Figure 5-1. Oxidizer Manifold Pressure

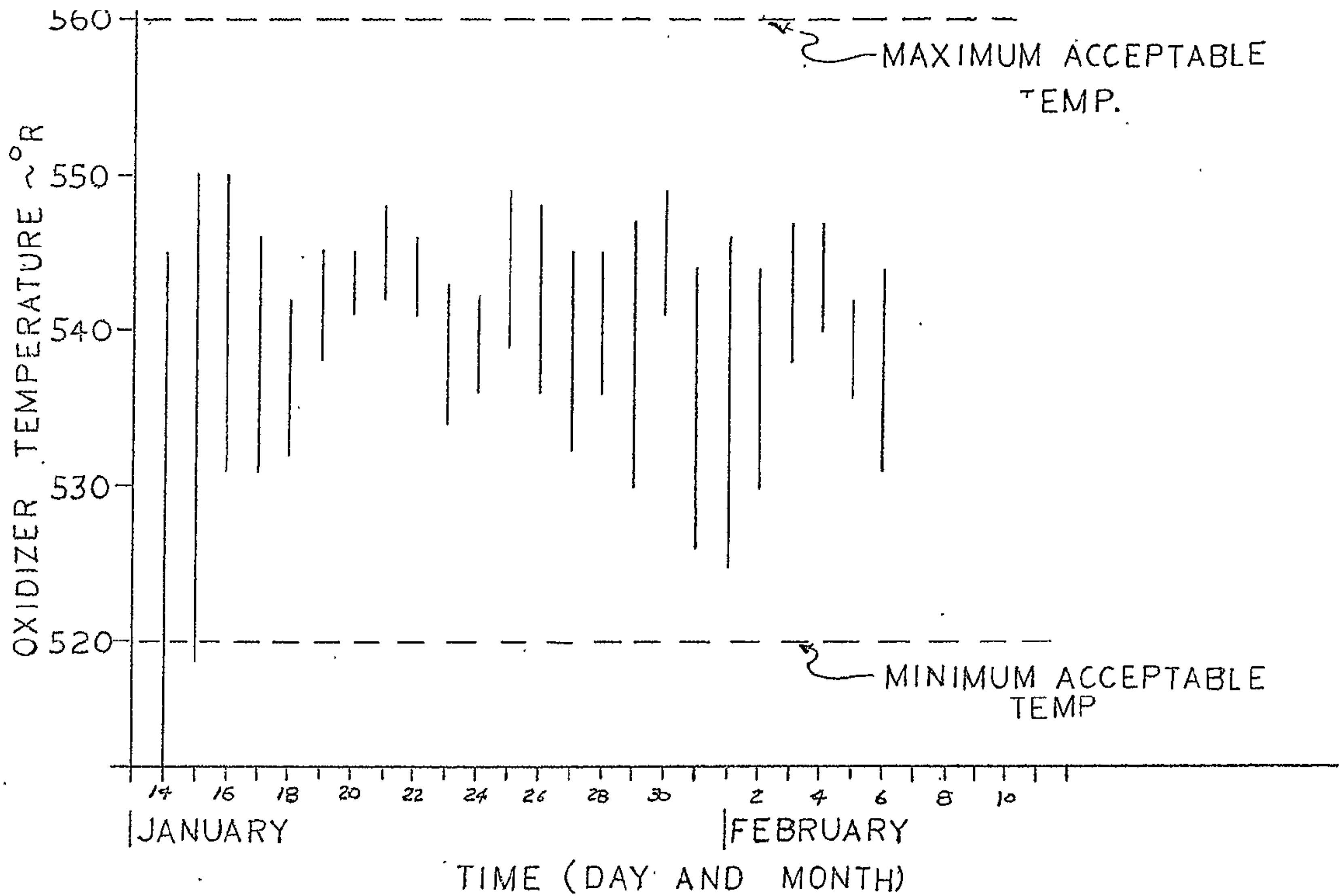


Figure 5-2. Oxidizer Temperature History

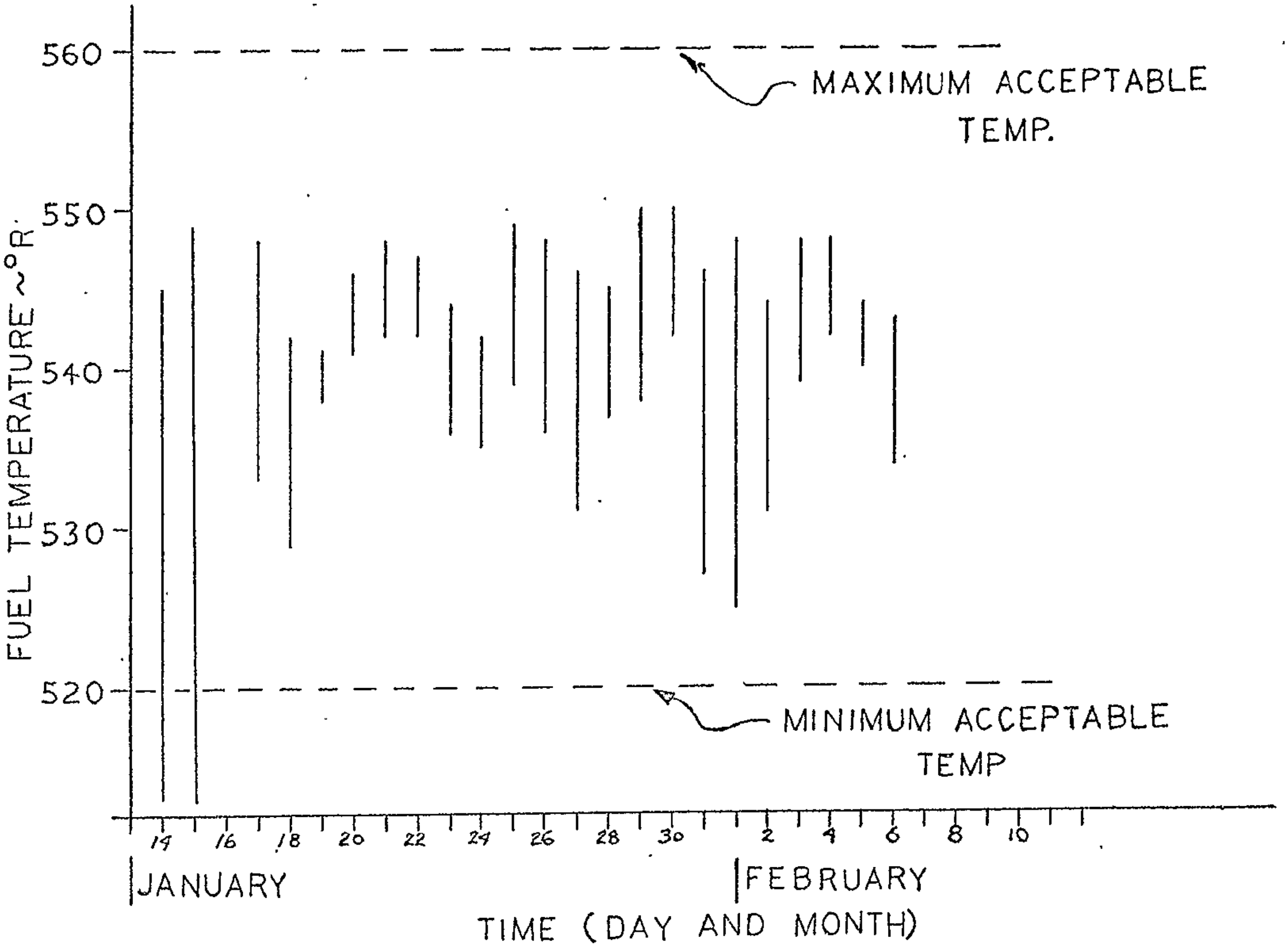


Figure 5-3. Fuel Temperature History

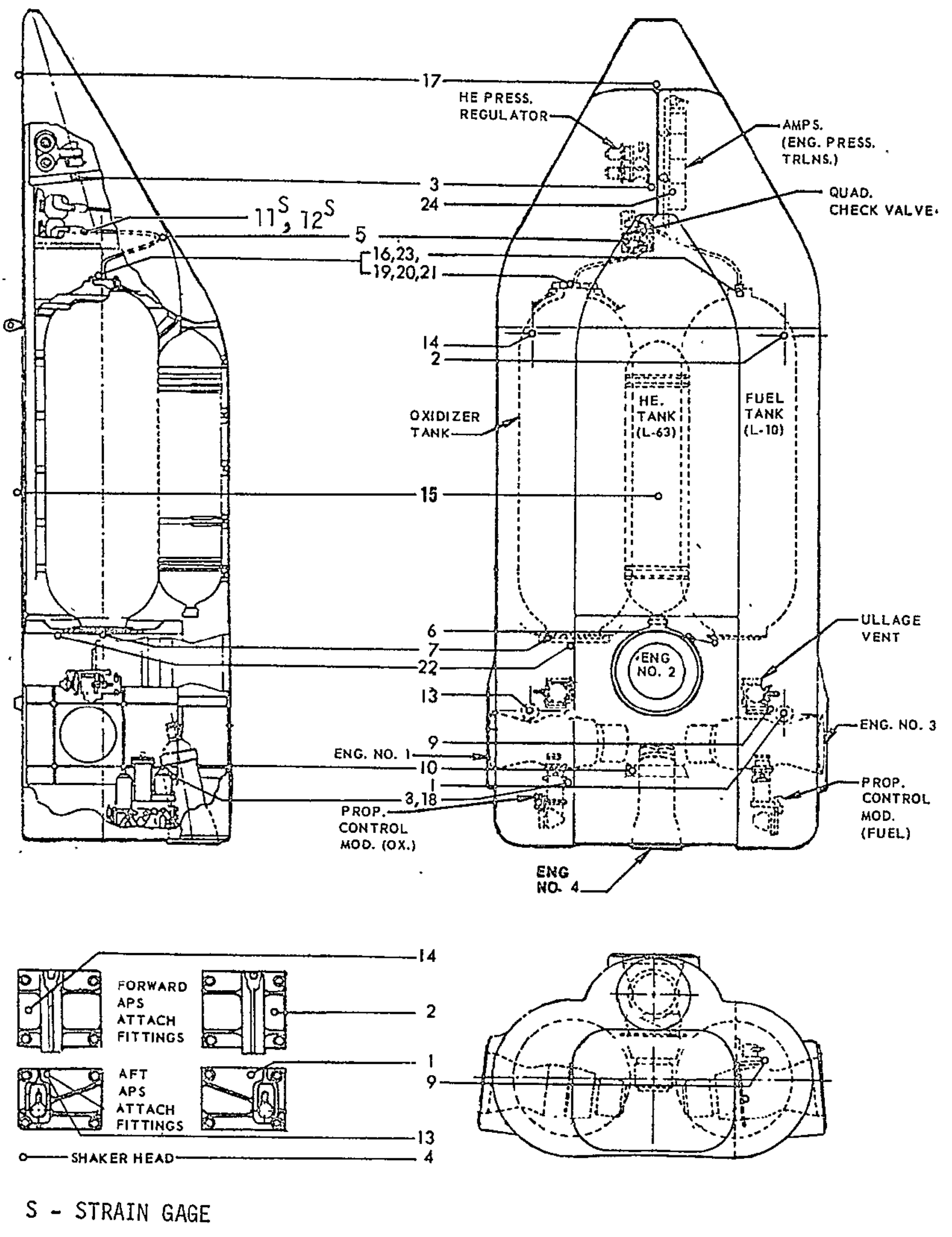


Figure 5-4. Accelerometer and Strain Gage Locations

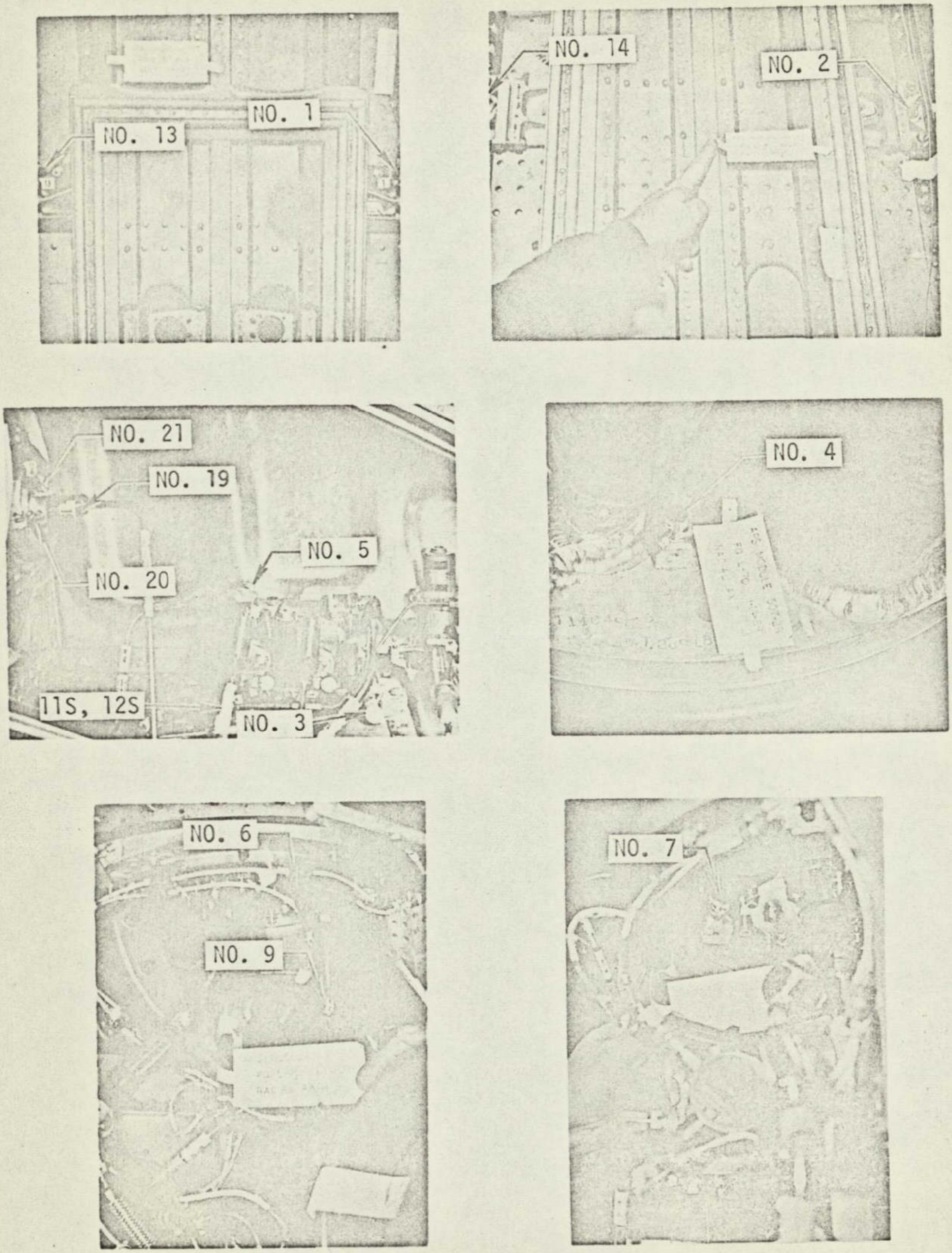


Figure 5-5. Radial Axis Accelerometer Locations (Sheet 1 of 2)

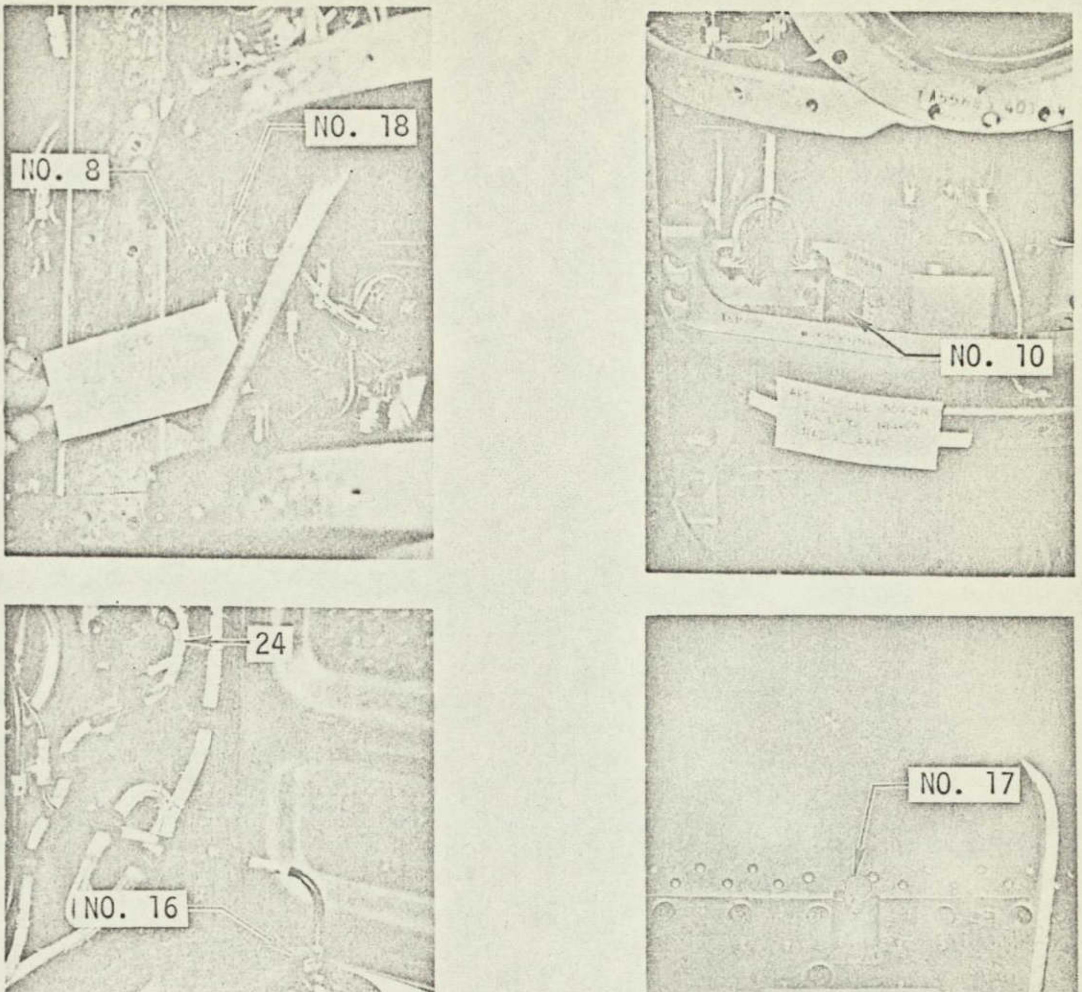


Figure 5-5. Radial Axis Accelerometer Locations (Sheet 2 of 2)

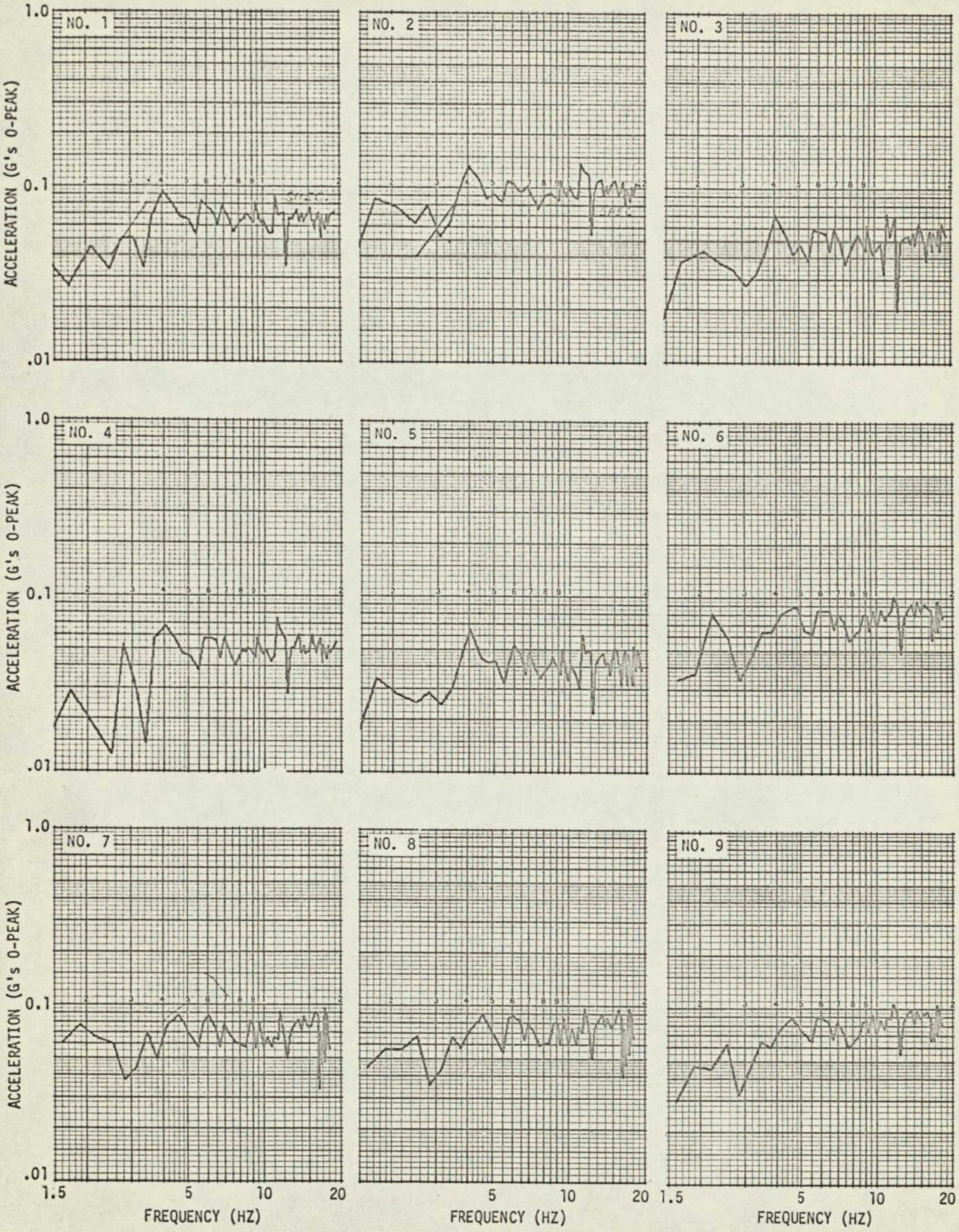


Figure 5-6 Radial Axis Sinusoidal Sweep (Sheet 1 of 3)

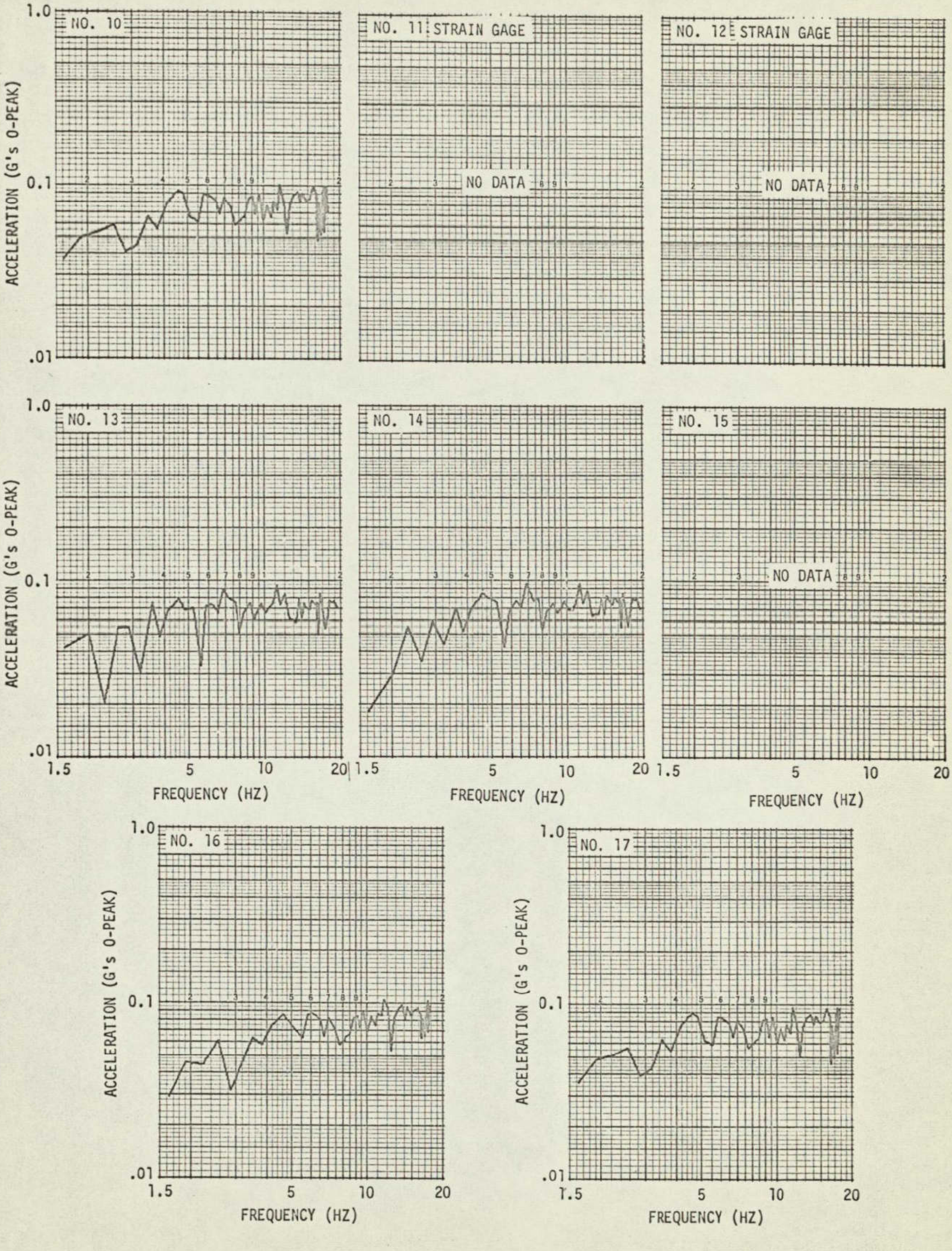


Figure 5-6 Radial Axis Sinusoidal Sweep (Sheet 2 of 3)

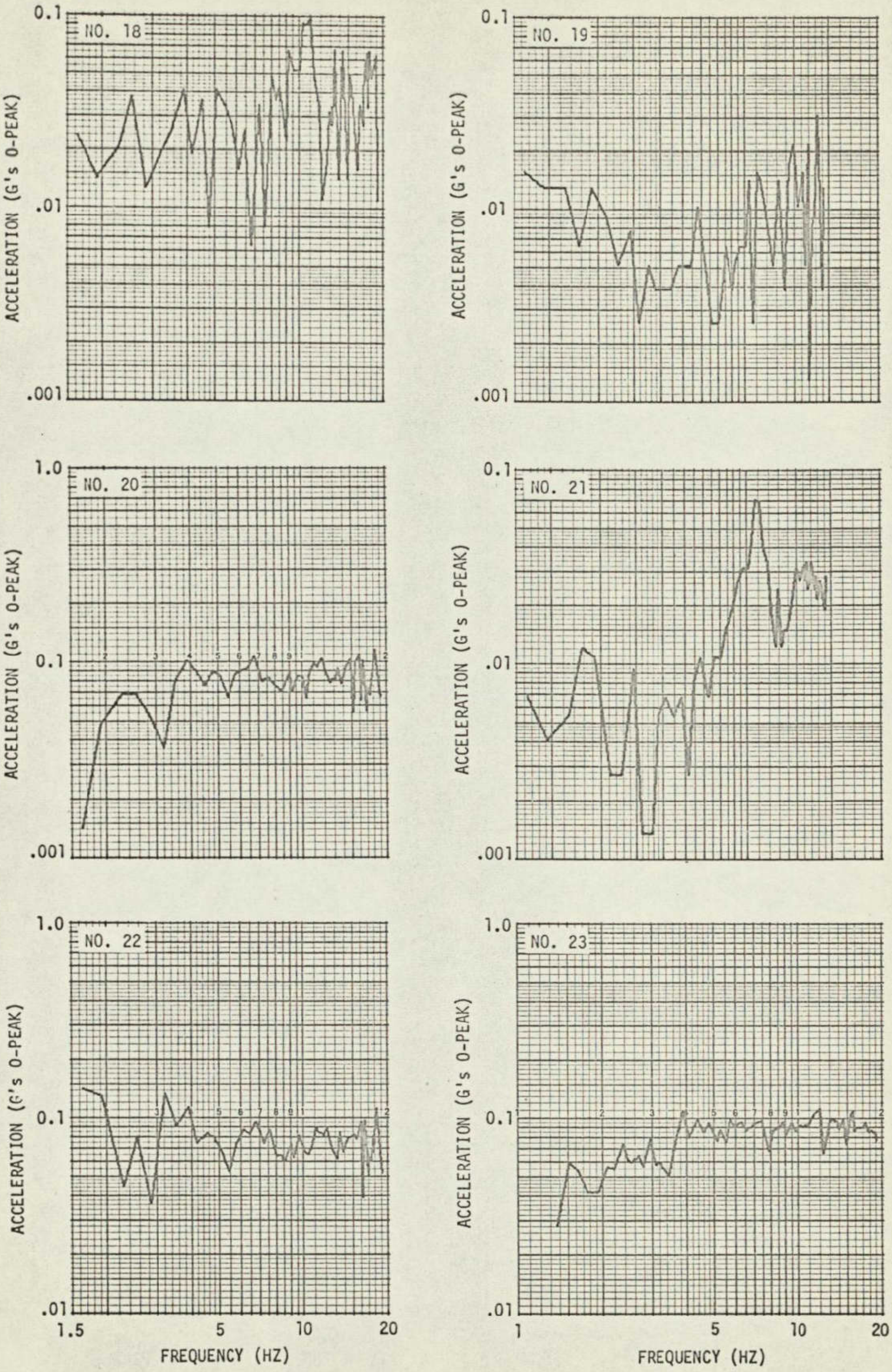


Figure 5-6 Radial Axis Sinusoidal Sweep (Sheet 3 of 3)

2

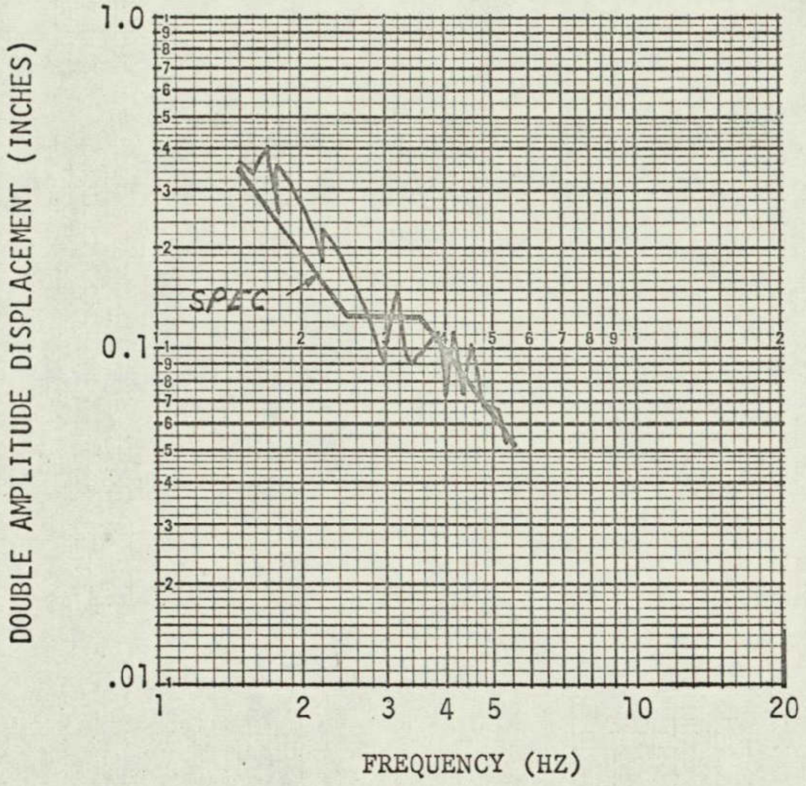


Figure 5-7. Fixture Displacement

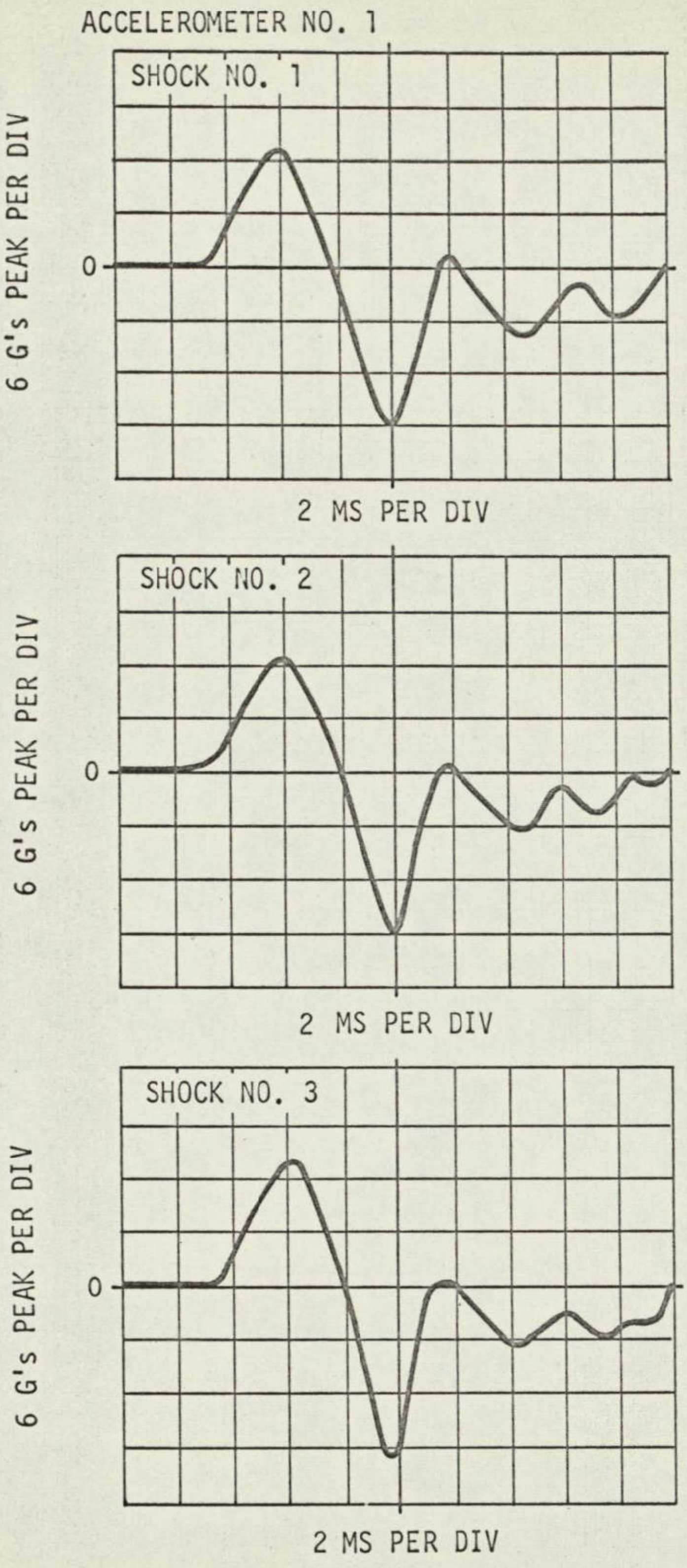


Figure 5-8. Radial Axis Shock Input

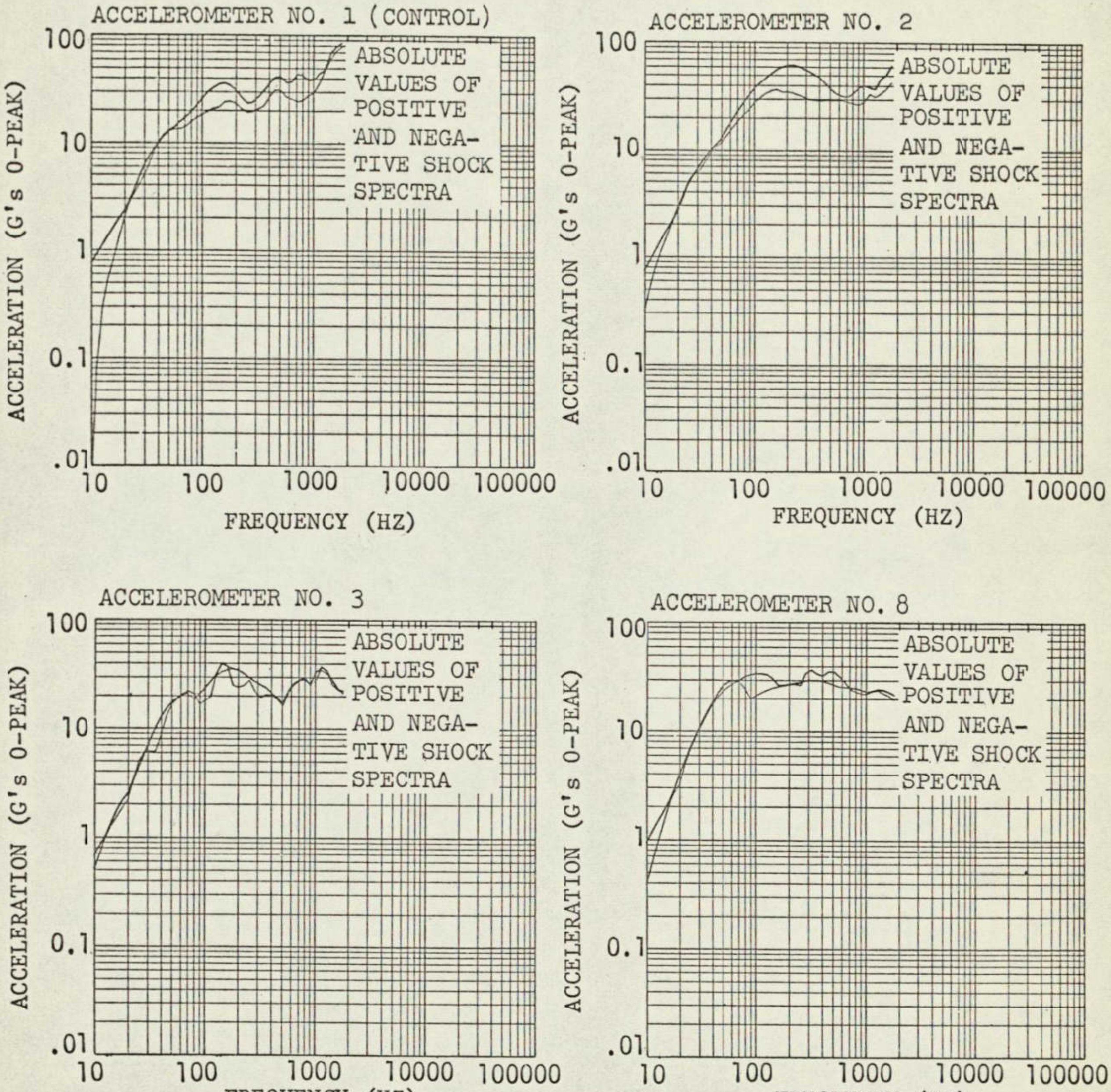
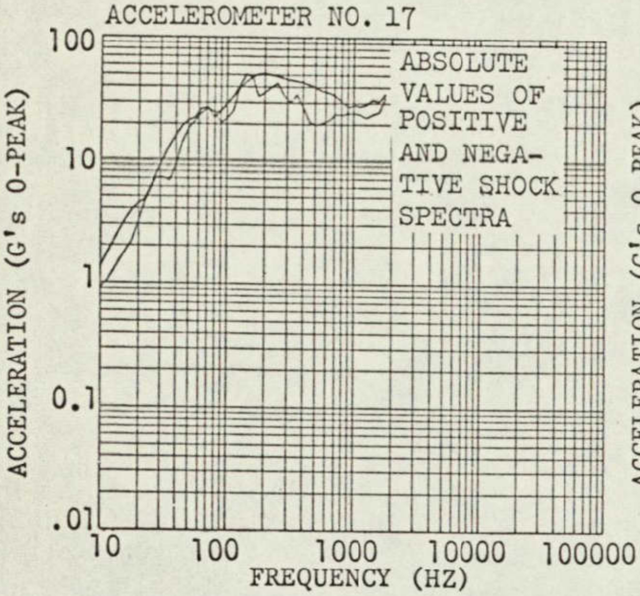
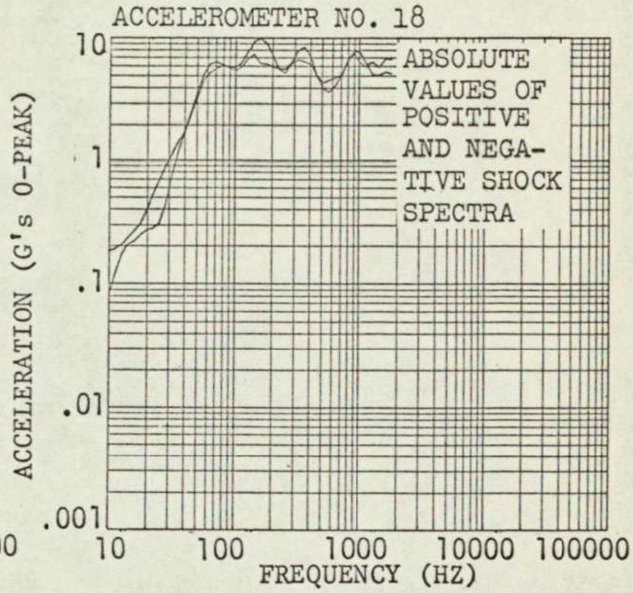


Figure 5-9. Radial Axis Shock Spectrum (Sheet 1 of 2)





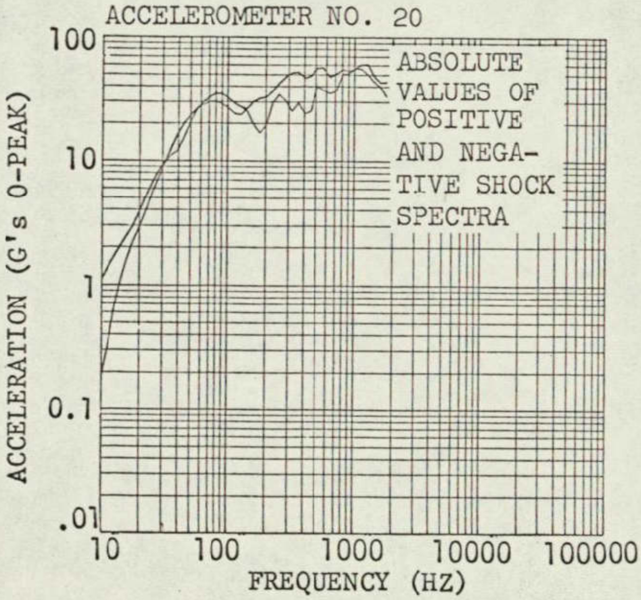


Figure 5-9. Radial Axis Shock Spectrum (Sheet 2 of 2)

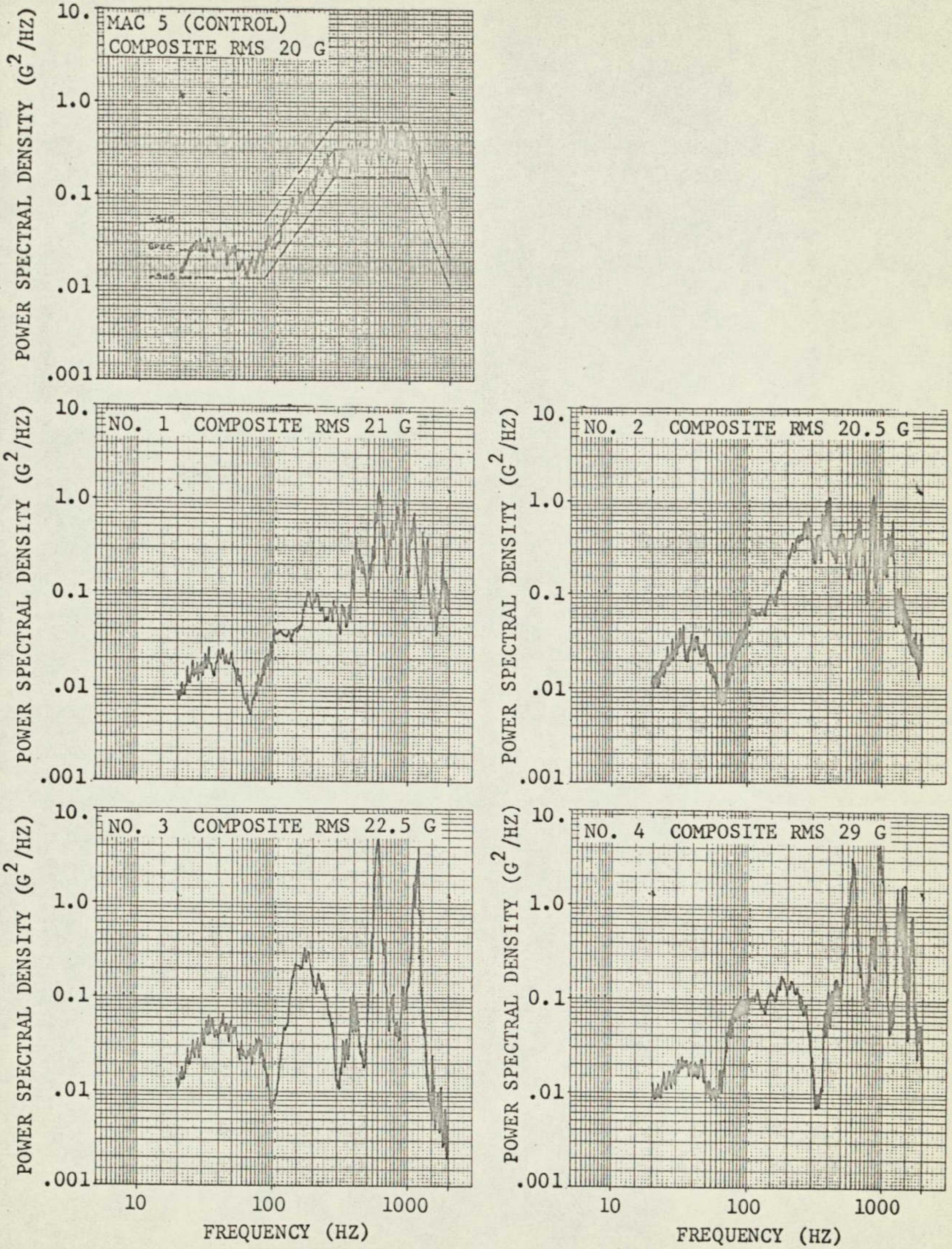


Figure 5-10. Radial Axis Low Level Random Vibration (Phase I) (Sheet 1 of 5)

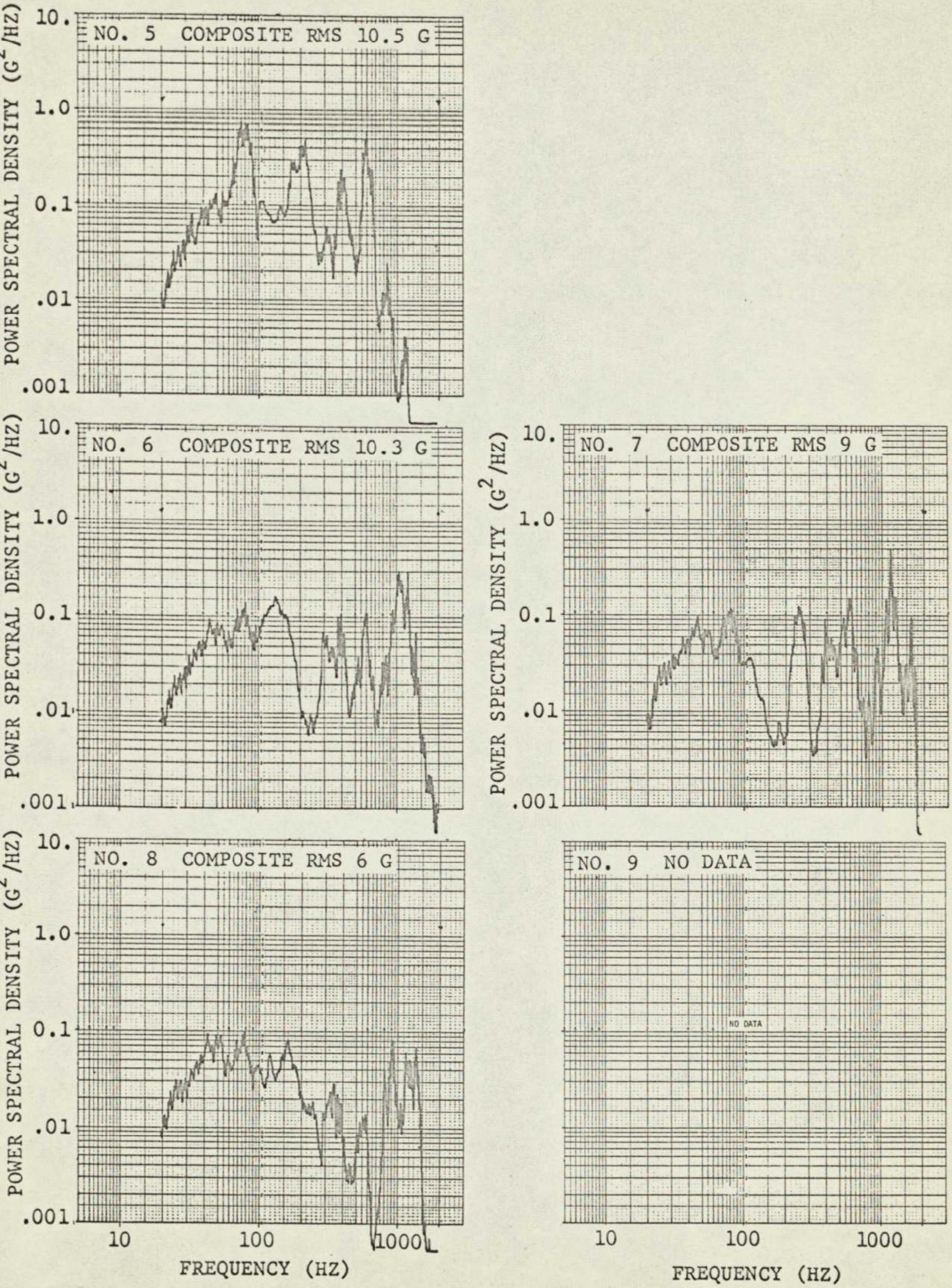


Figure 5-10. Radial Axis Low Level Random Vibration (Phase I) (Sheet 2 of 5)

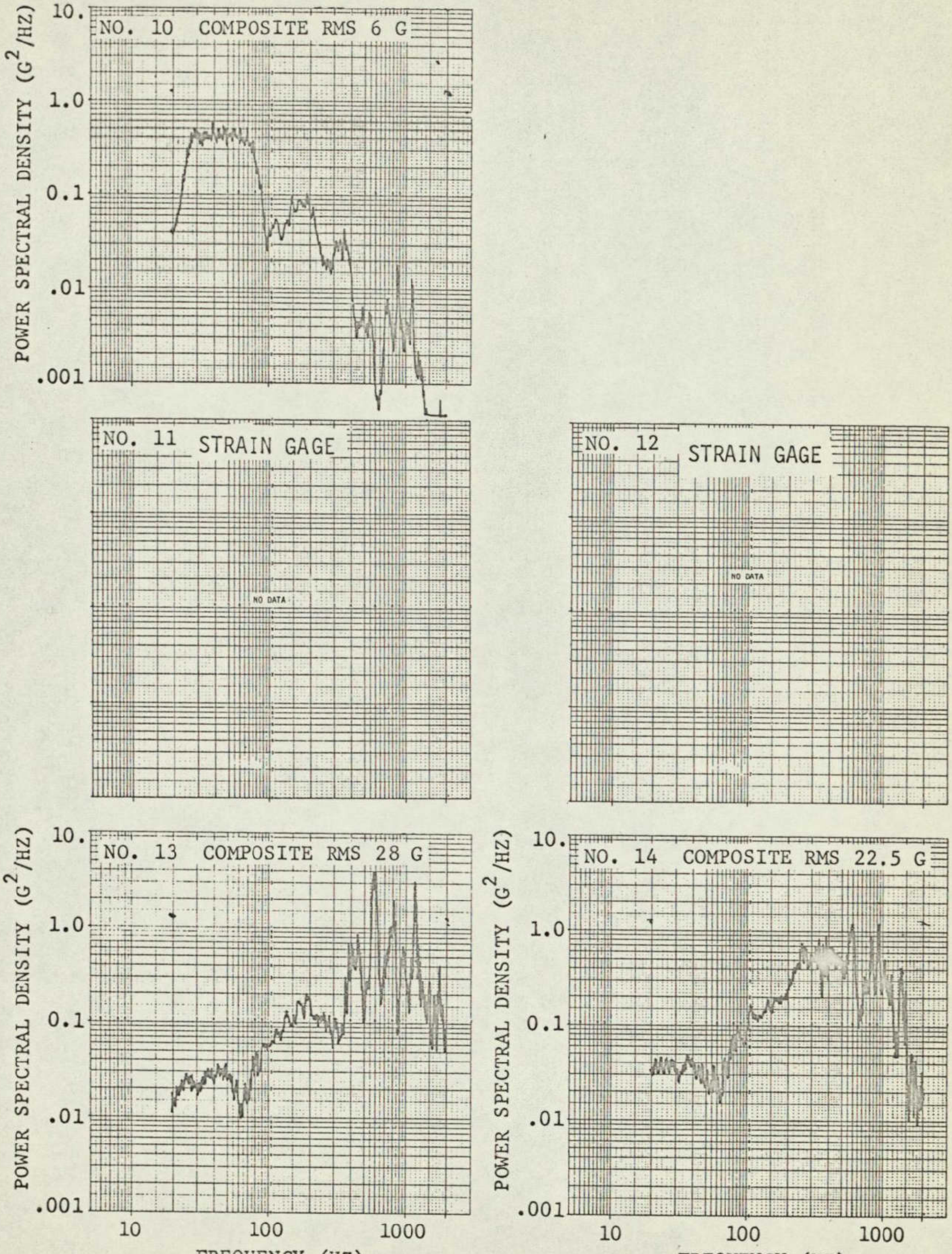


Figure 5-10. Radial Axis Low Level Random Vibration (Phase I) (Sheet 3 of 5)

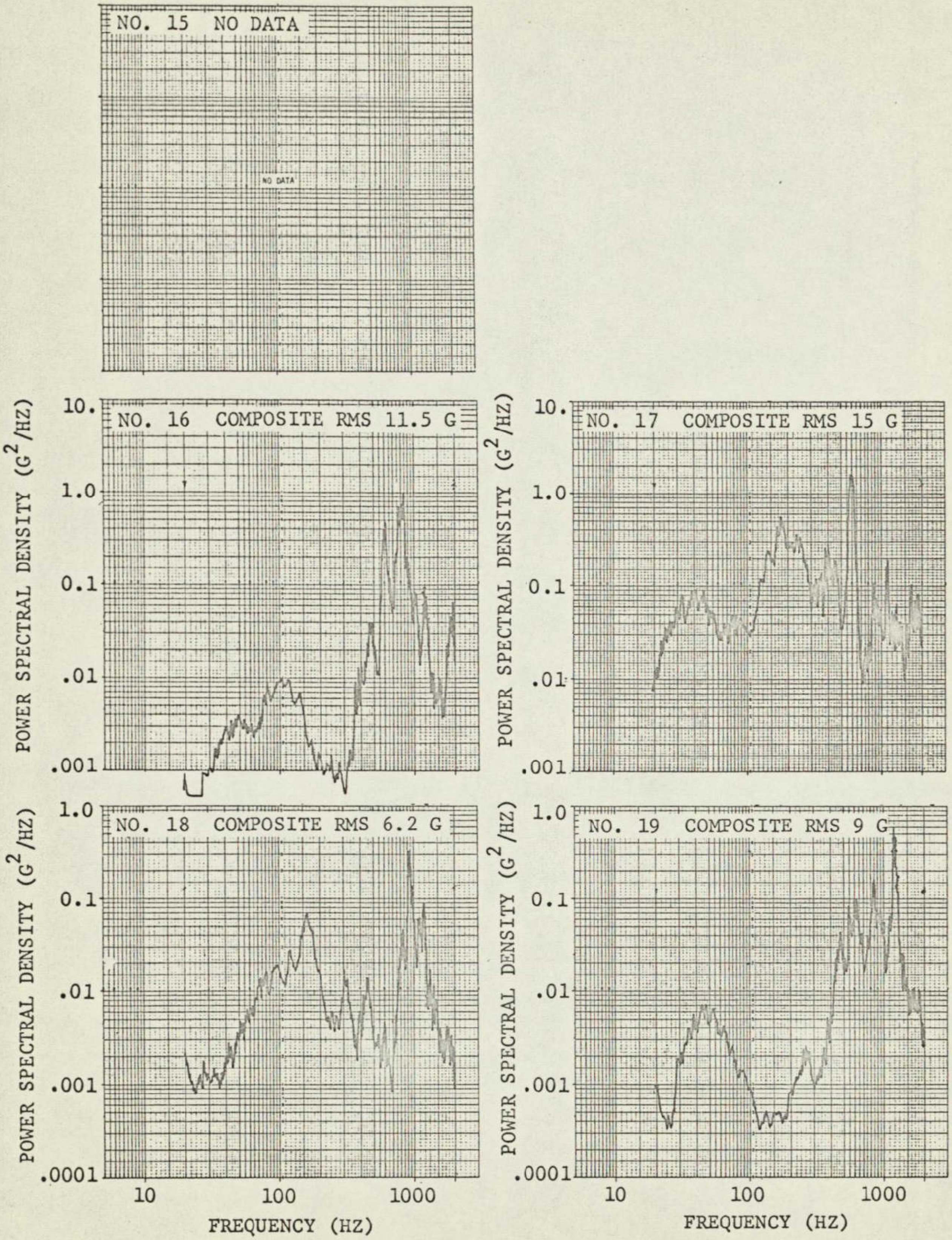


Figure 5-10. Radial Axis Low Level Random Vibration (Phase I) (Sheet 4 of 5)

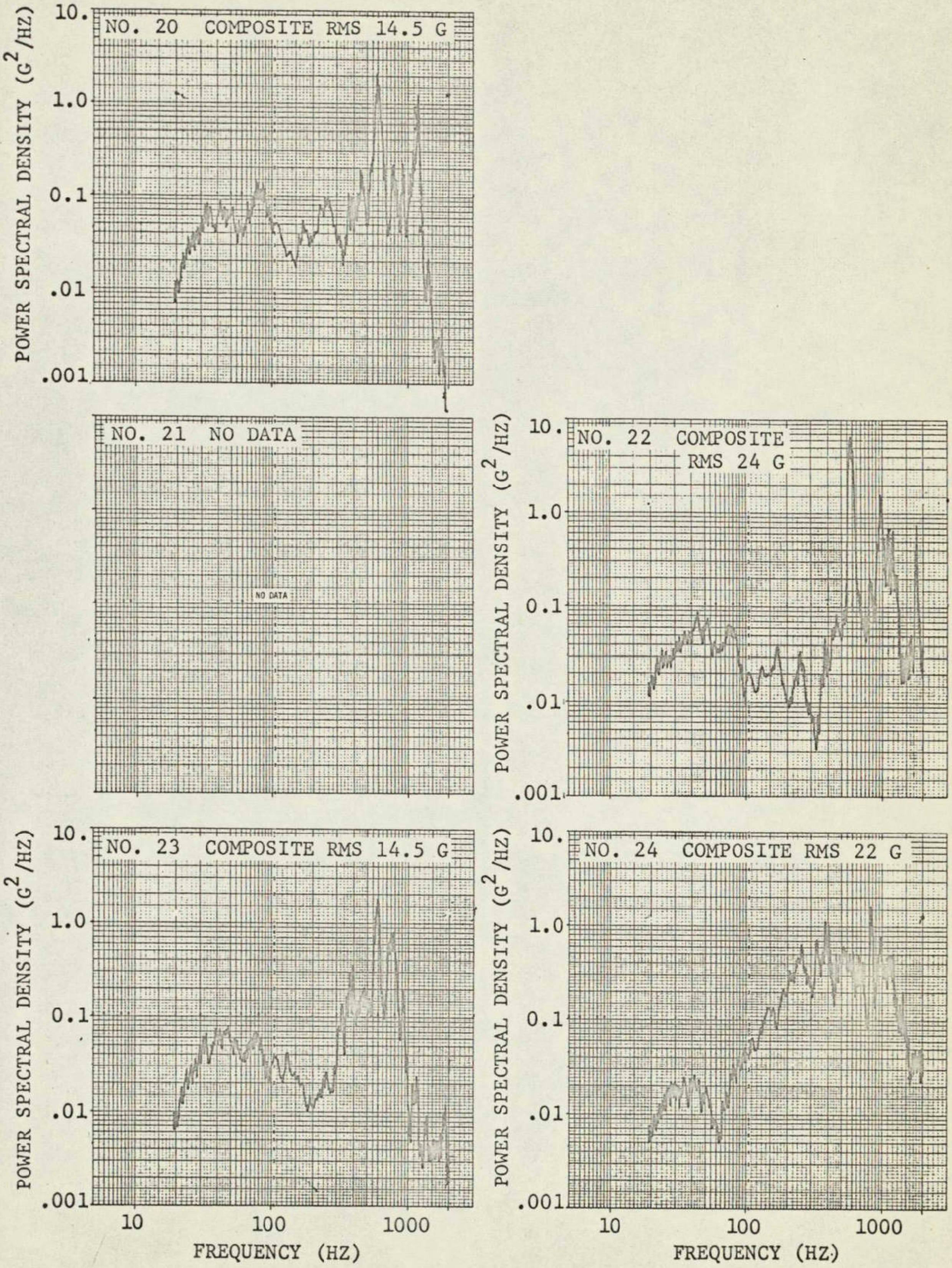


Figure 5-10. Radial Axis Low Level Random Vibration (Phase I) (Sheet 5 of 5)

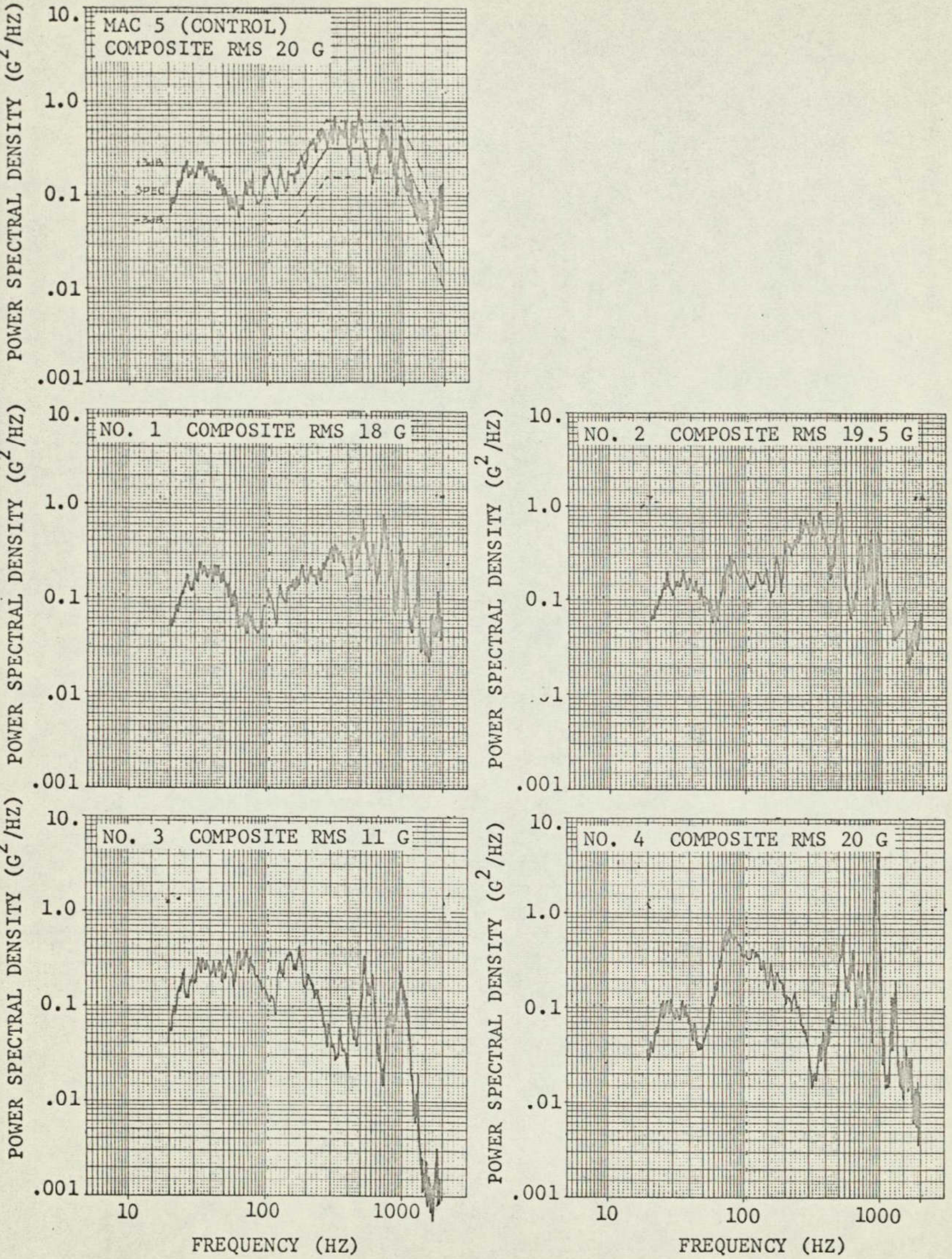


Figure 5-11. Radial Axis High Level Random Vibration (Phase II) (Sheet 1 of 5)

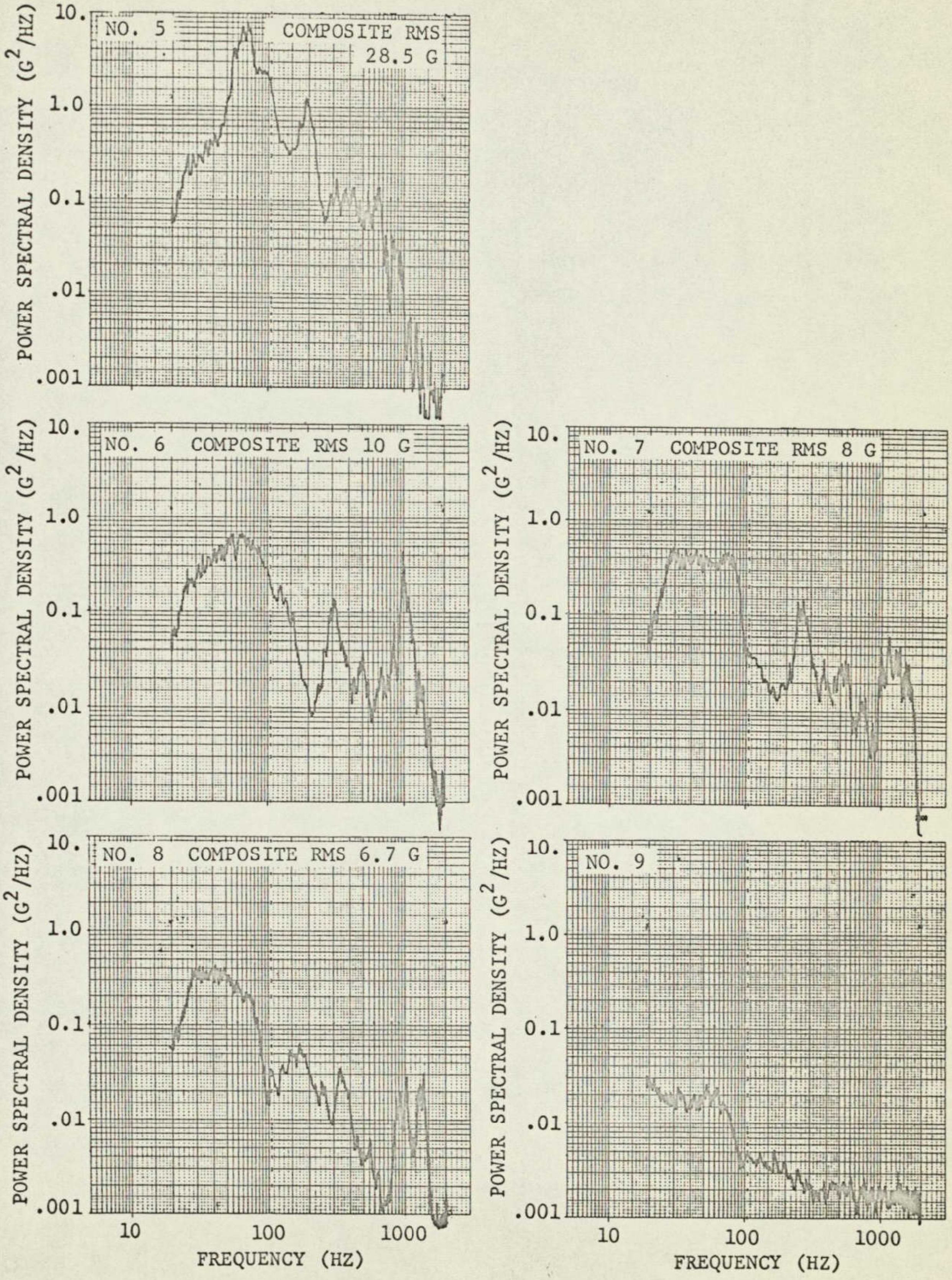


Figure 5-11. Radial Axis High Level Random Vibration (Phase II) (Sheet 2 of 5)

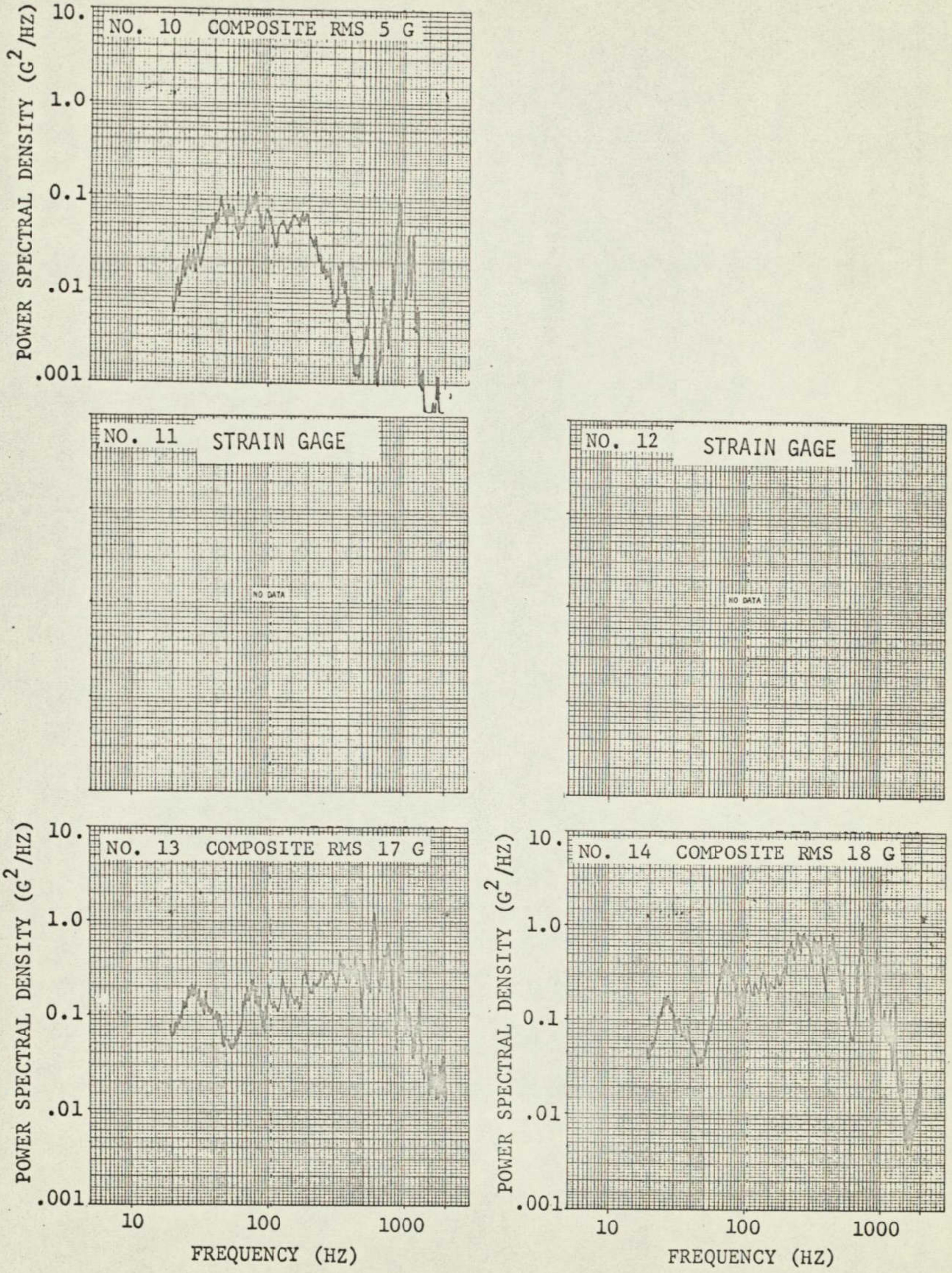


Figure 5-11. Radial Axis High Level Random Vibration (Phase II) (Sheet 3 of 5)

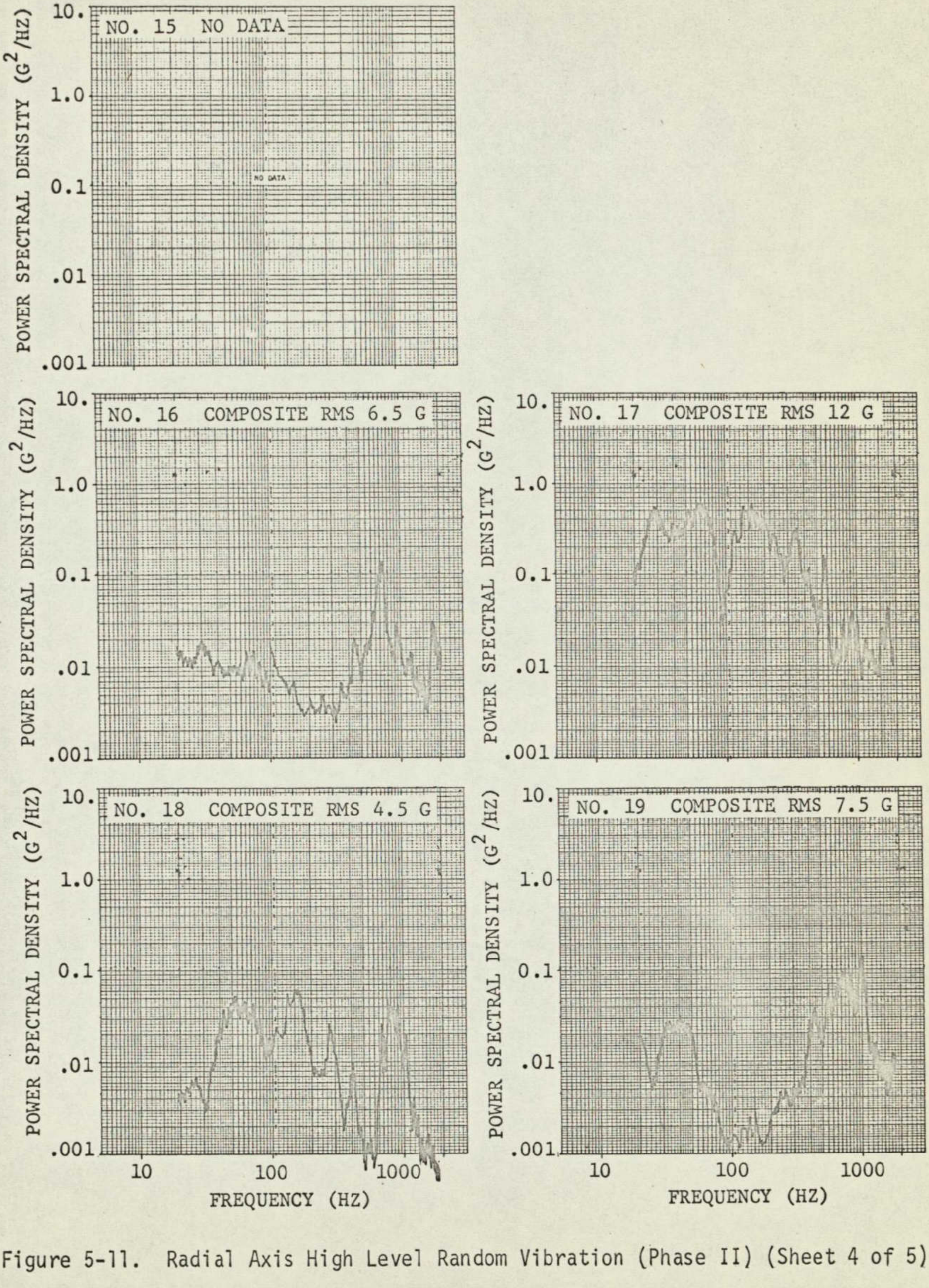


Figure 5-11. Radial Axis High Level Random Vibration (Phase II) (Sheet 4 of 5)

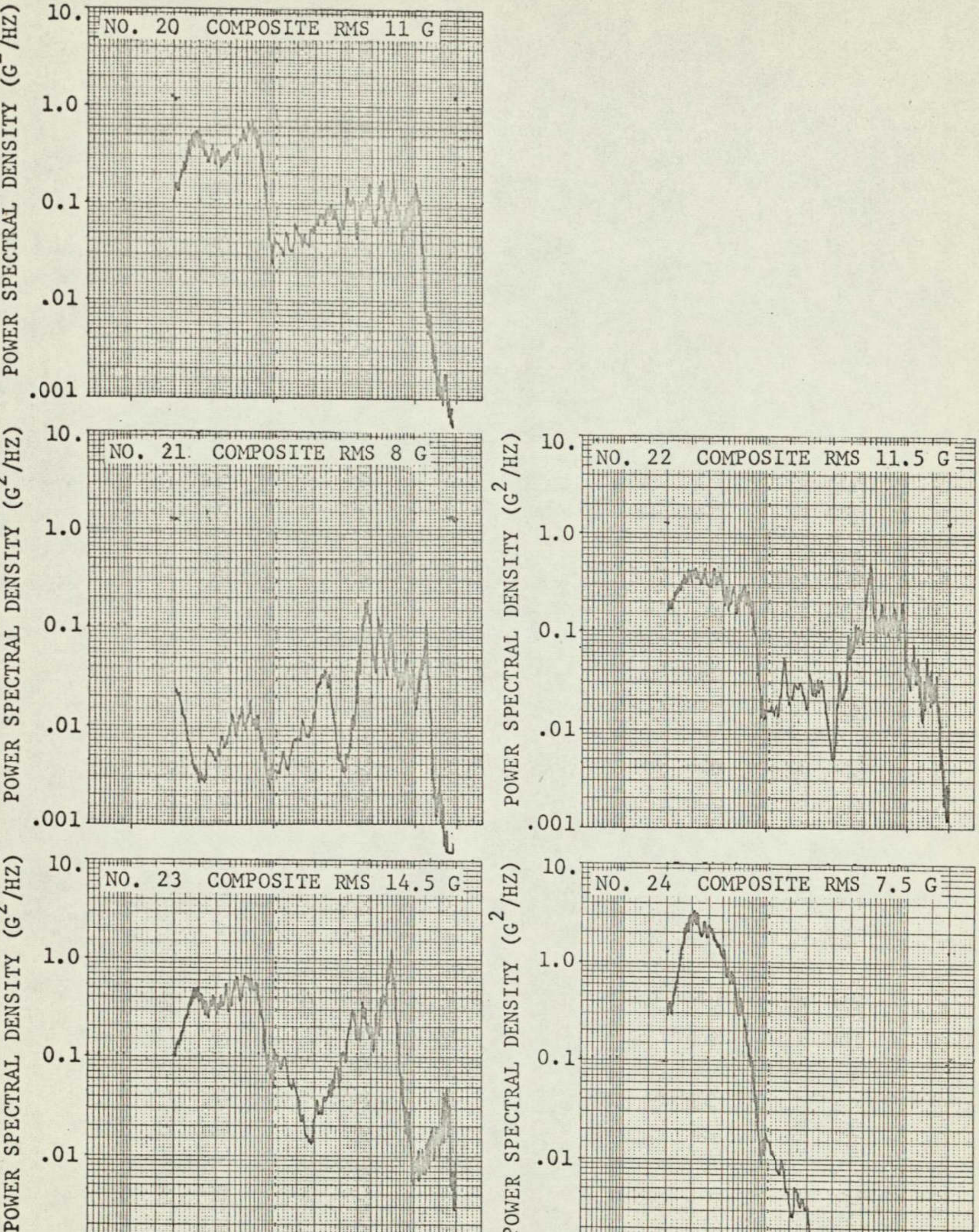


Figure 5-11. Radial Axis High Level Random Vibration (Phase II) (Sheet 5 of 5)

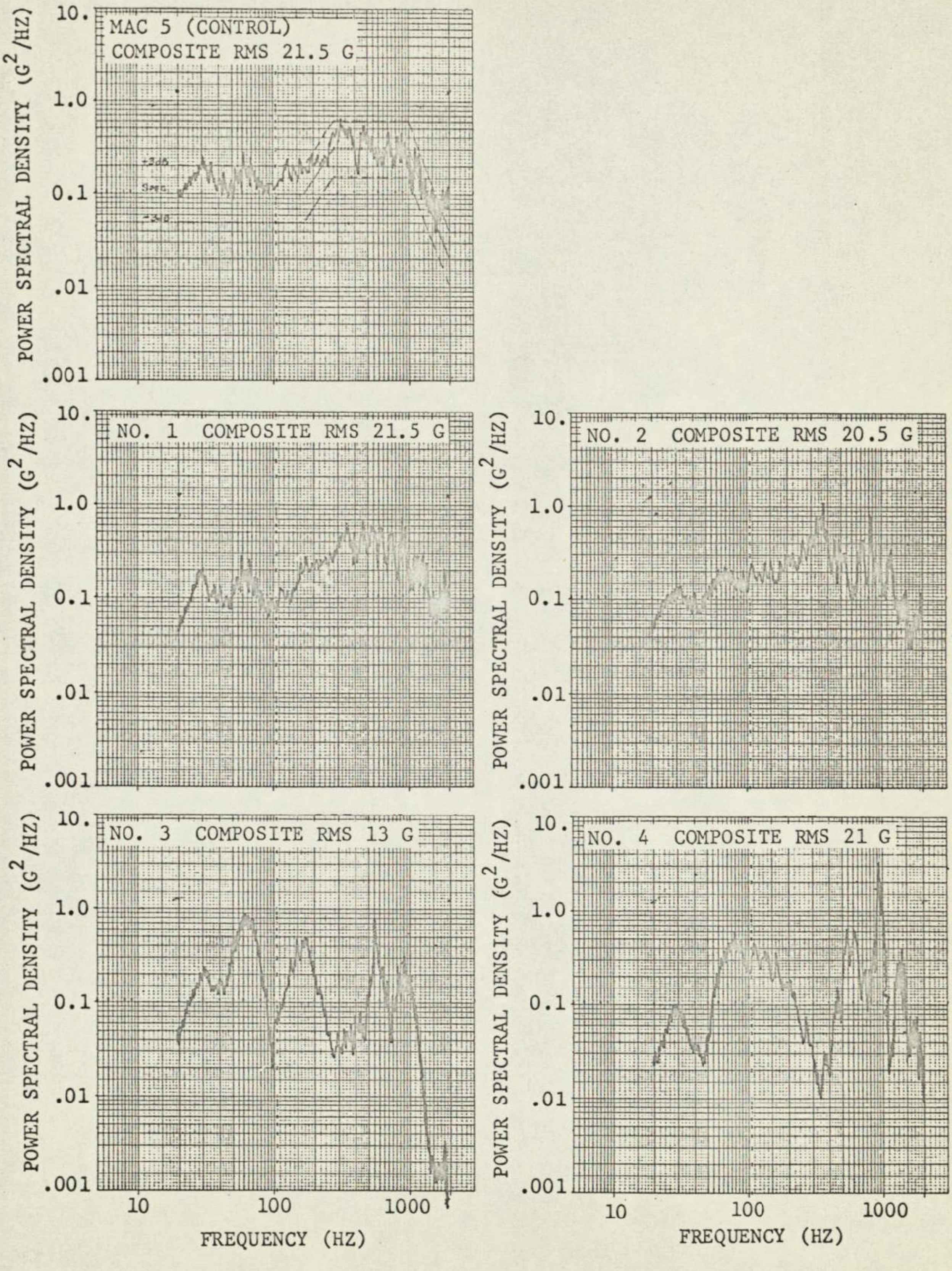


Figure 5-12. Radial Axis High Level Random Vibration (Phase III) (Sheet 1 of 5)

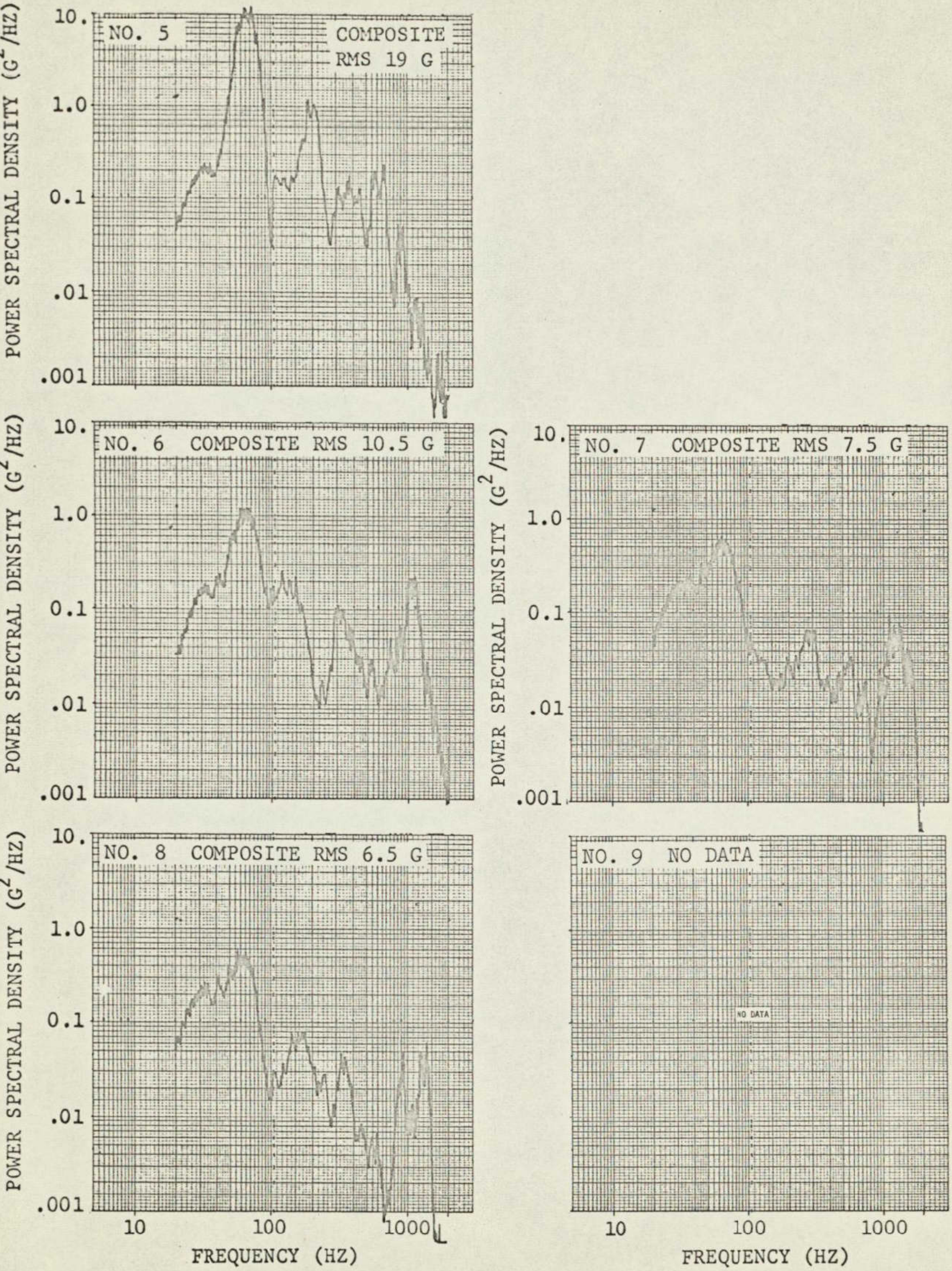


Figure 5-12. Radial Axis High Level Random Vibration (Phase III) (Sheet 2 of 5)

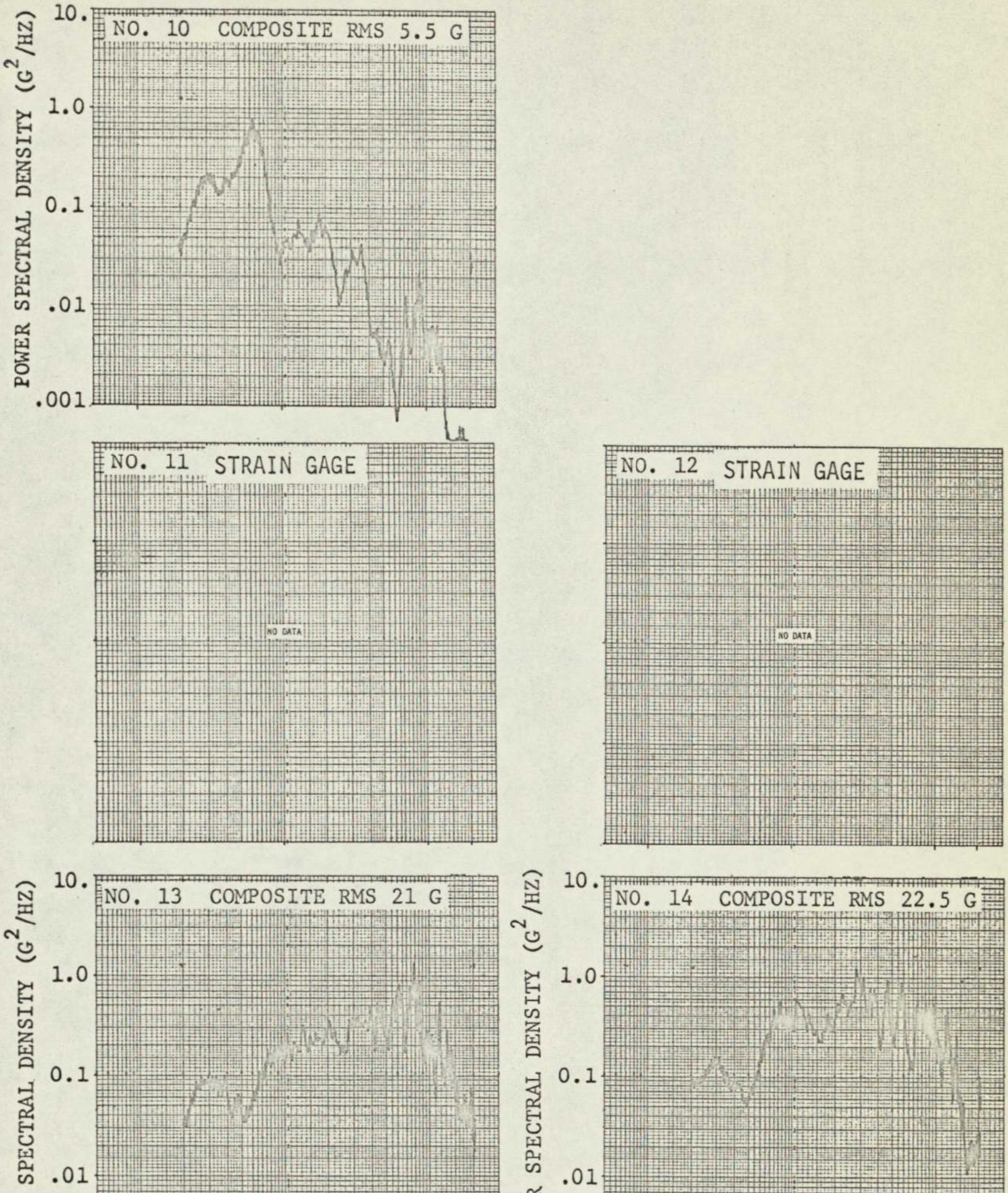


Figure 5-12. Radial Axis High Level Random Vibration (Phase III) (Sheet 3 of 5)

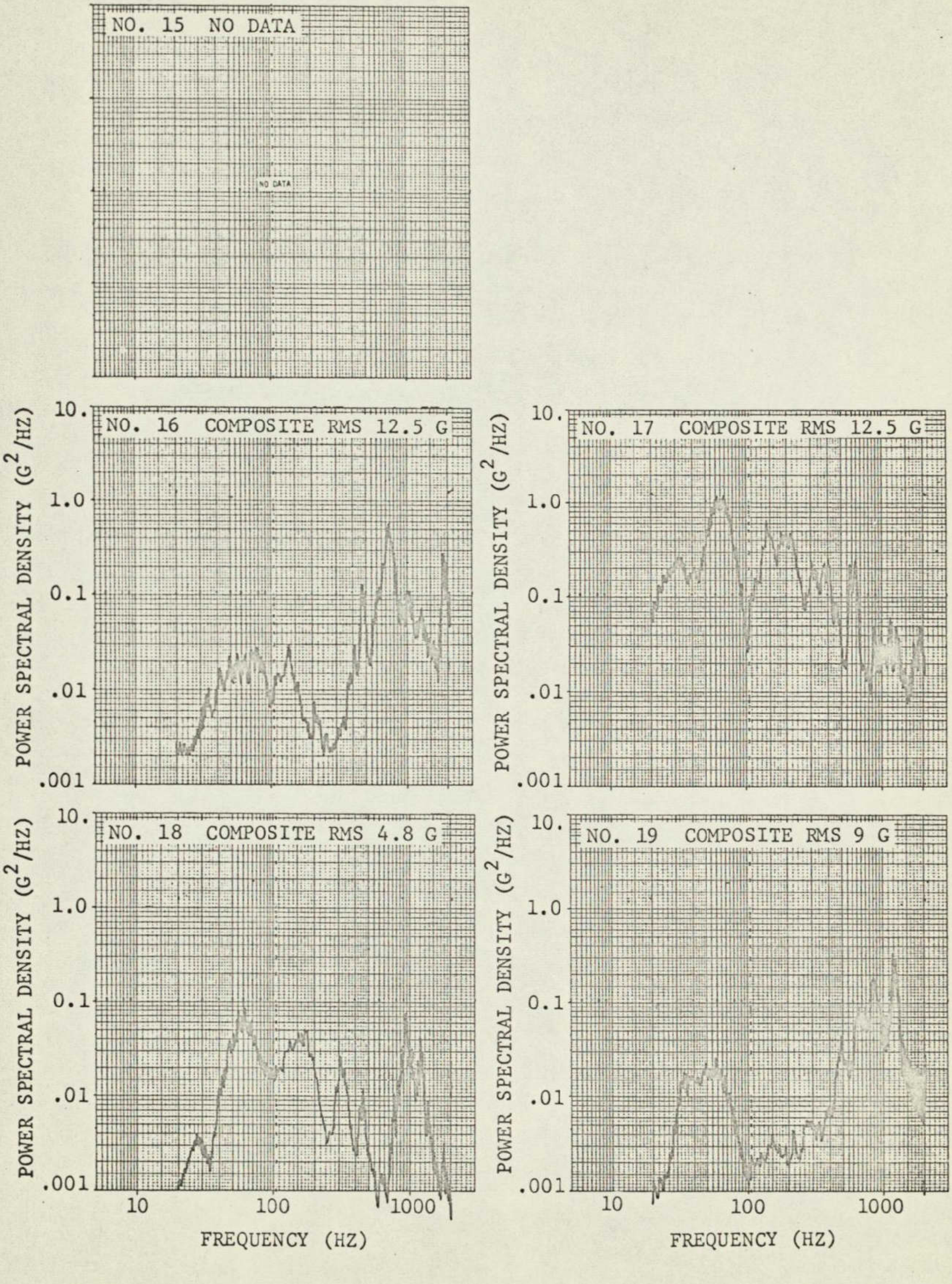


Figure 5-12. Radial Axis High Level Random Vibration (Phase III) (Sheet 4 of 5)

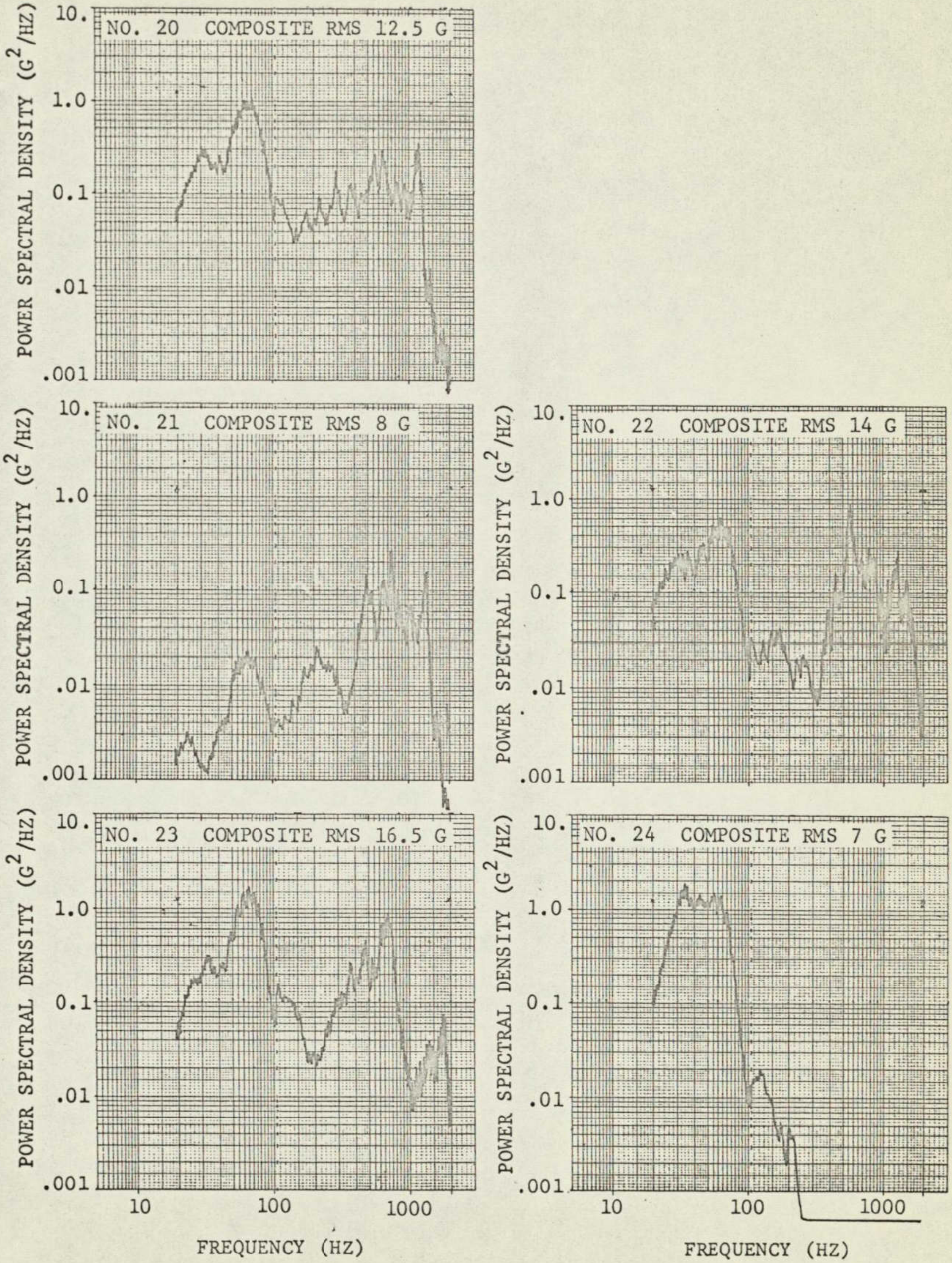


Figure 5-12. Radial Axis High Level Random Vibration (Phase III) (Sheet 5 of 5)

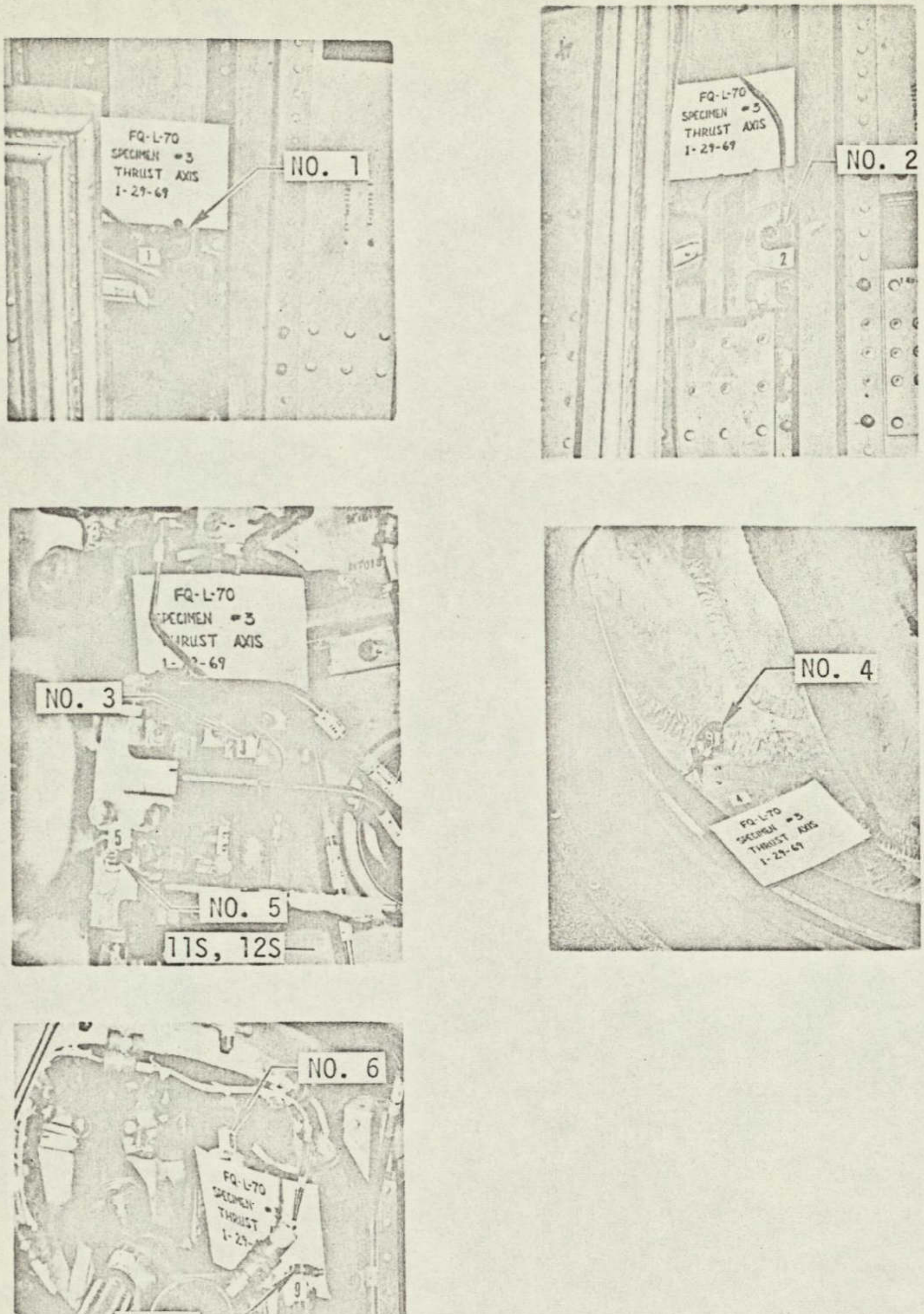
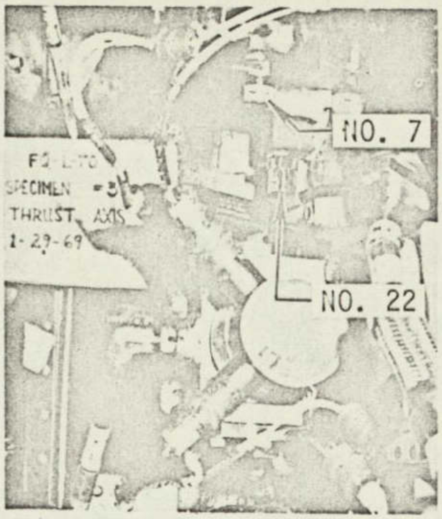
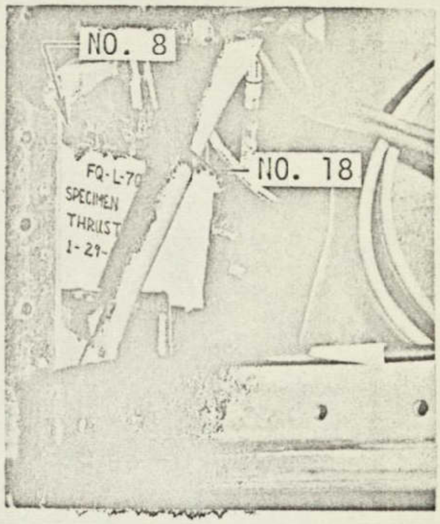
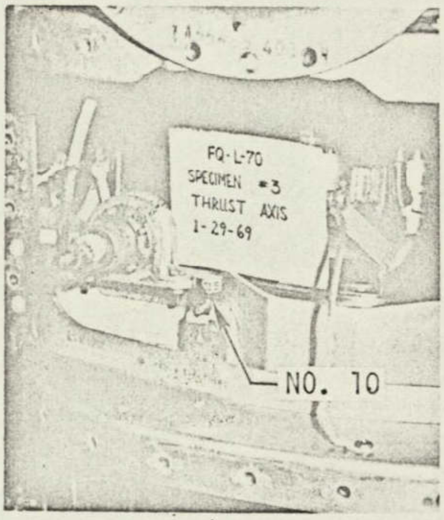
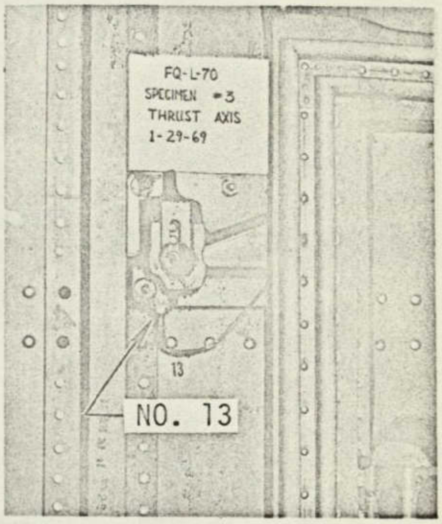


Figure 5-13. Thrust Axis Accelerometer Locations (Sheet 1 of 3)









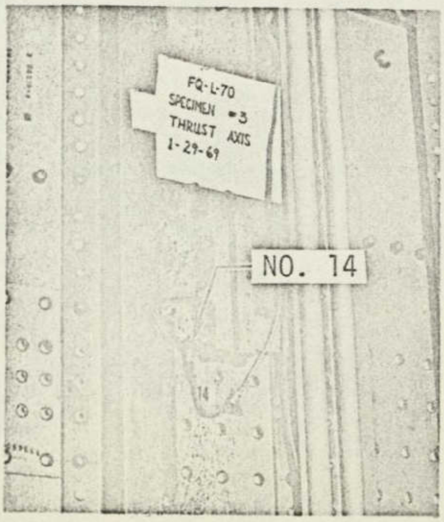
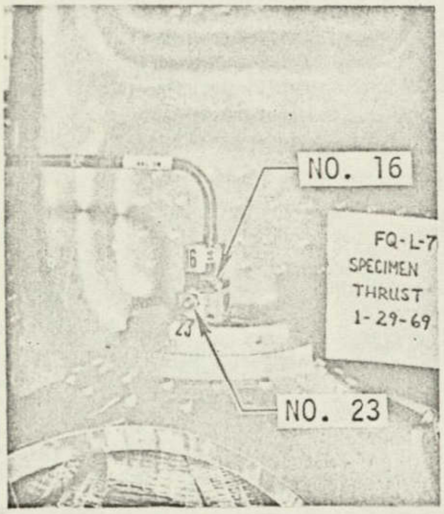
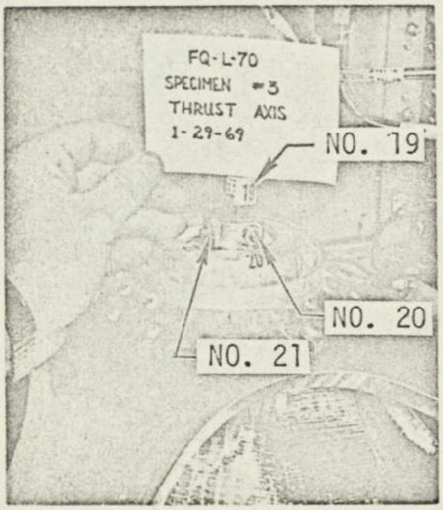


Figure 5-13. Thrust Axis Accelerometer Locations (Sheet 2 of 3)





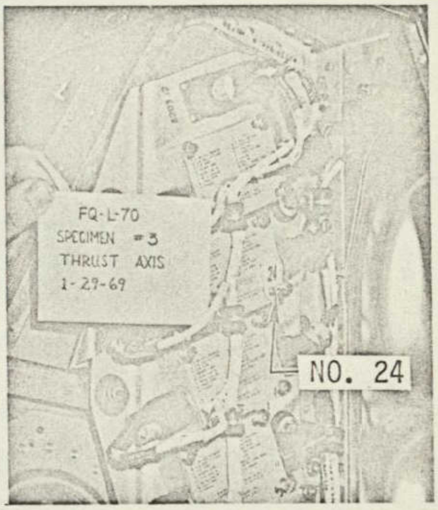


Figure 5-13. Thrust Axis Accelerometer Locations (Sheet 3 of 3)

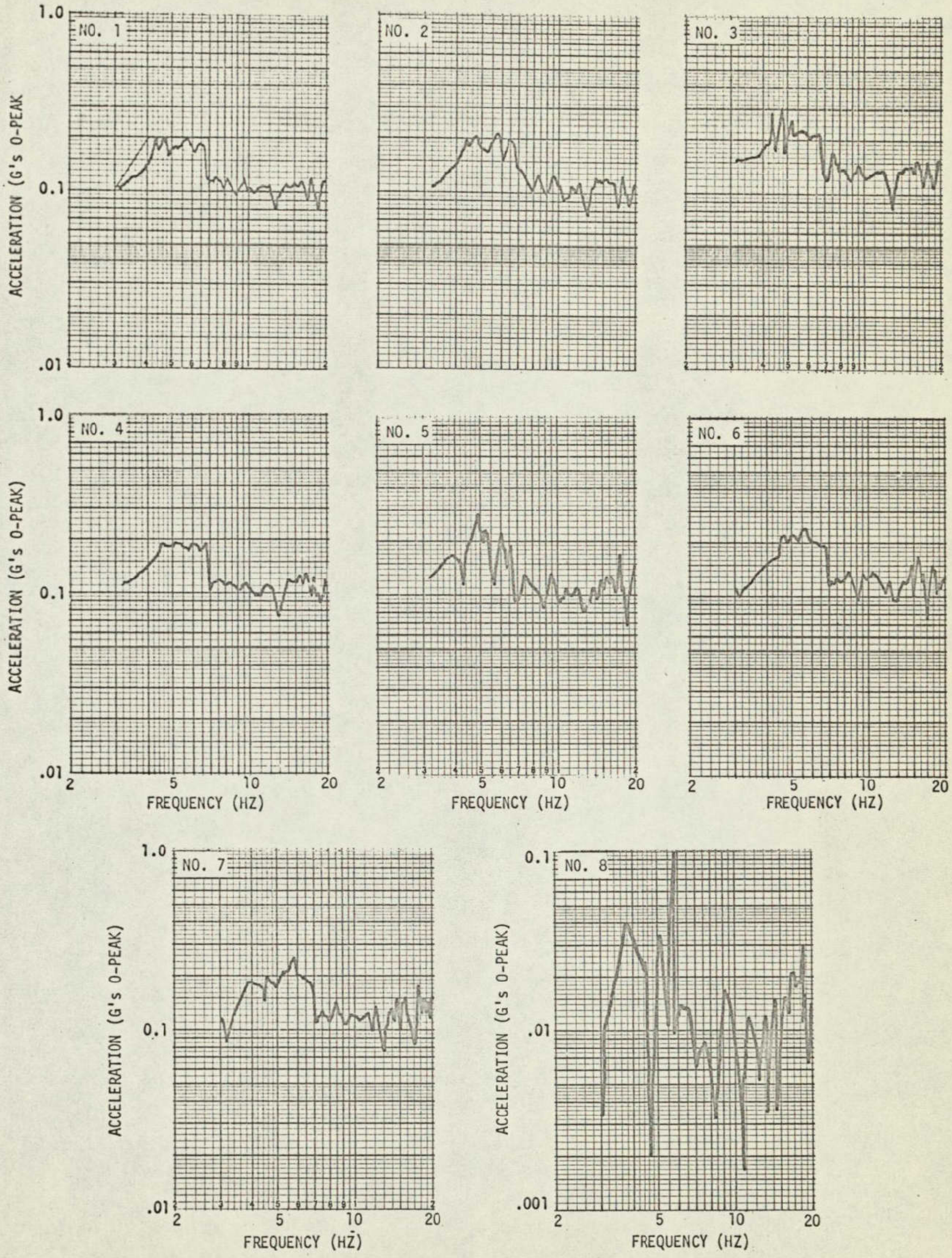


Figure 5-14 Thrust Axis Sinusoidal Sweep (Sheet 1 of 3)

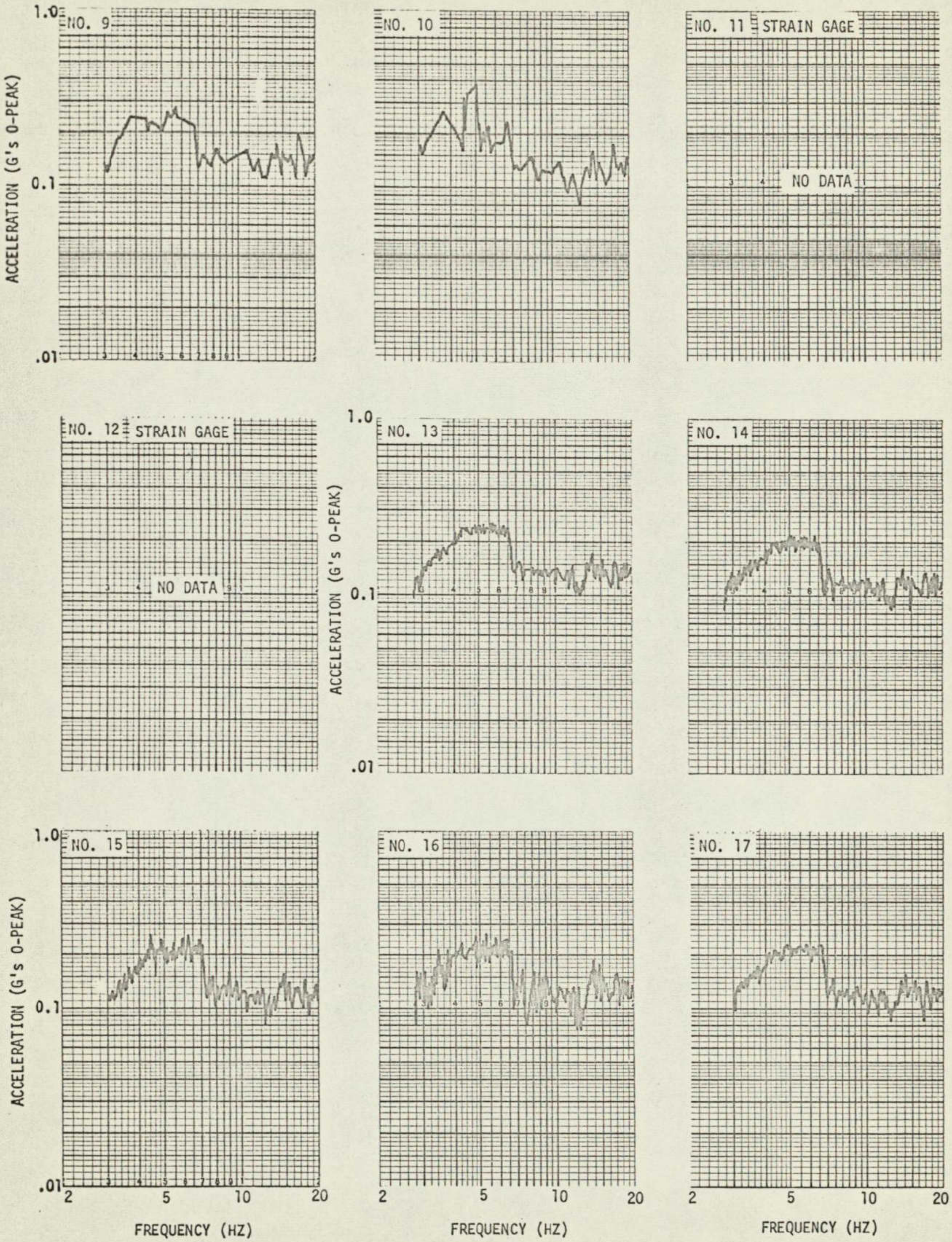


Figure 5-14 Thrust Axis Sinusoidal Sweep (Sheet 2 of 3)

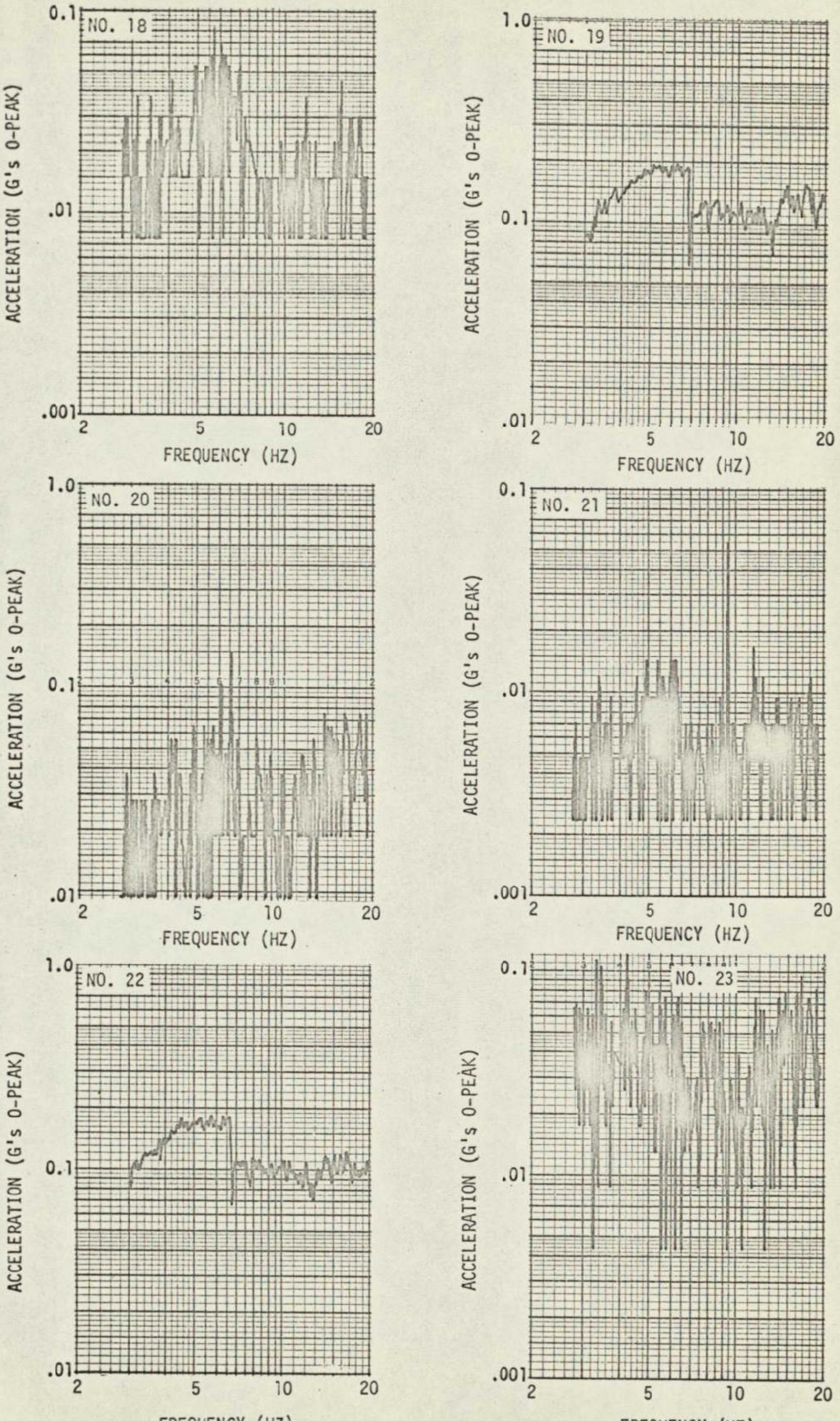


Figure 5-14 Thrust Axis Sinusoidal Sweep (Sheet 3 of 3)

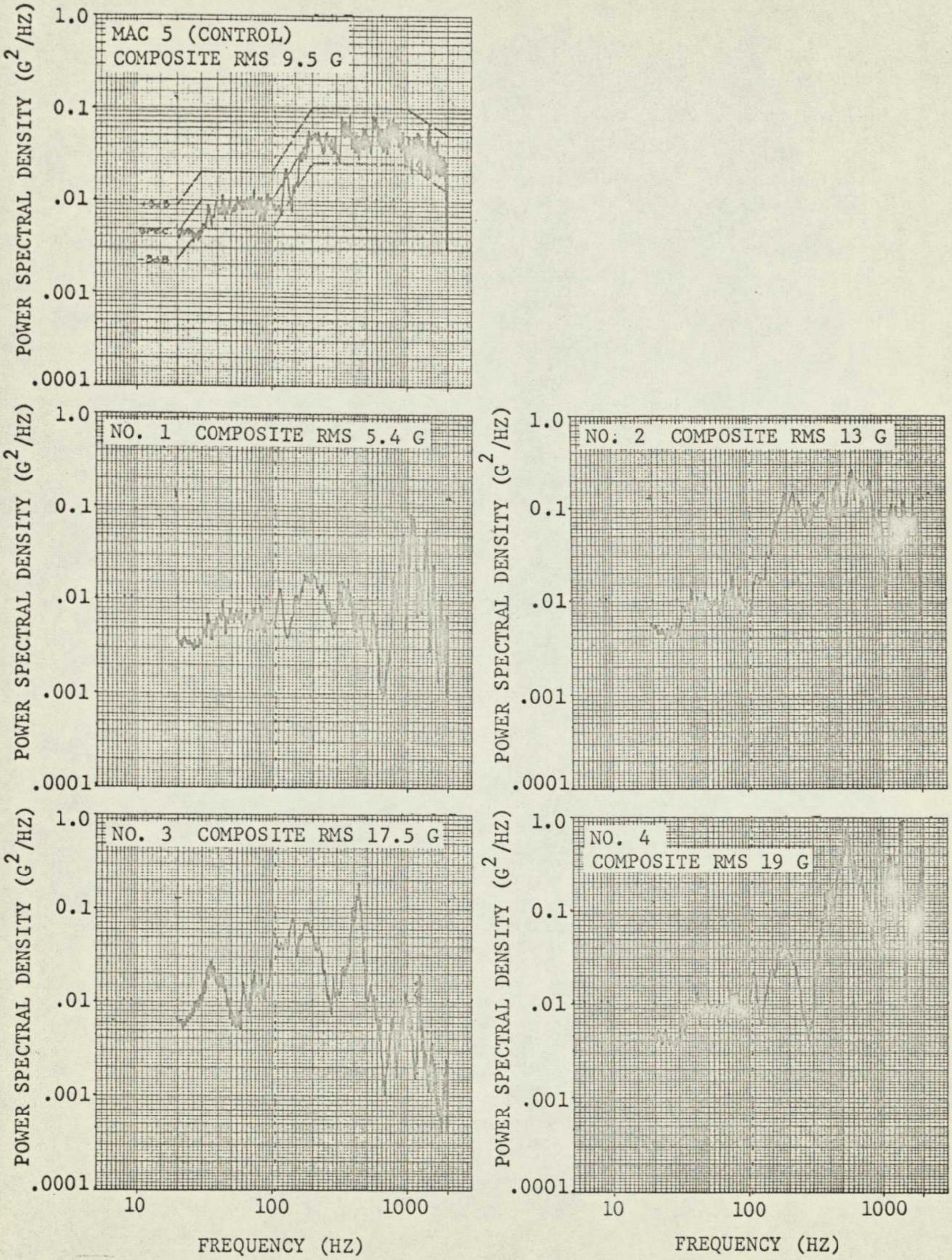


Figure 5-15. Thrust Axis Random Vibration (Sheet 1 of 5)

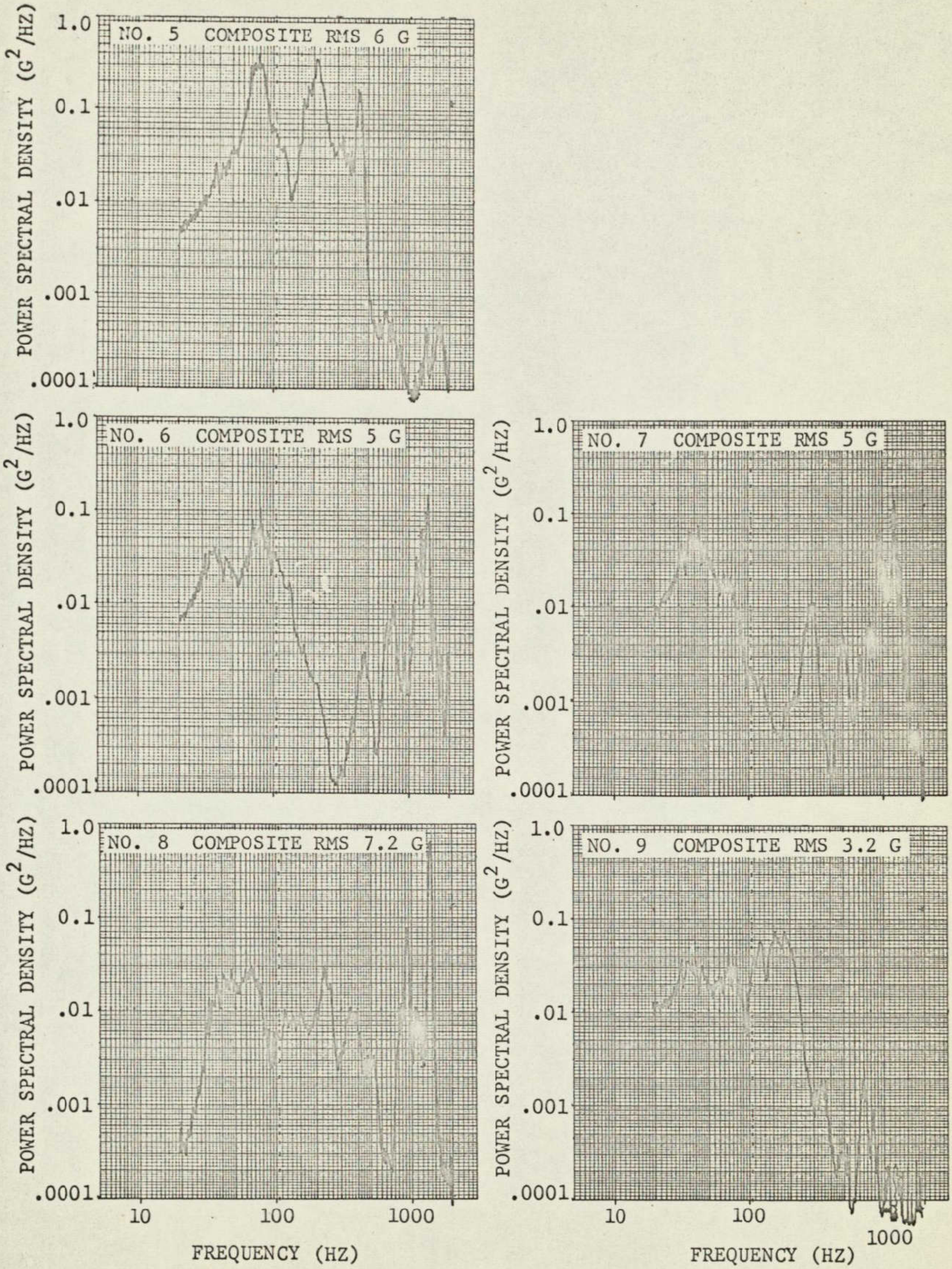


Figure 5-15. Thrust Axis Random Vibration (Sheet 2 of 5)

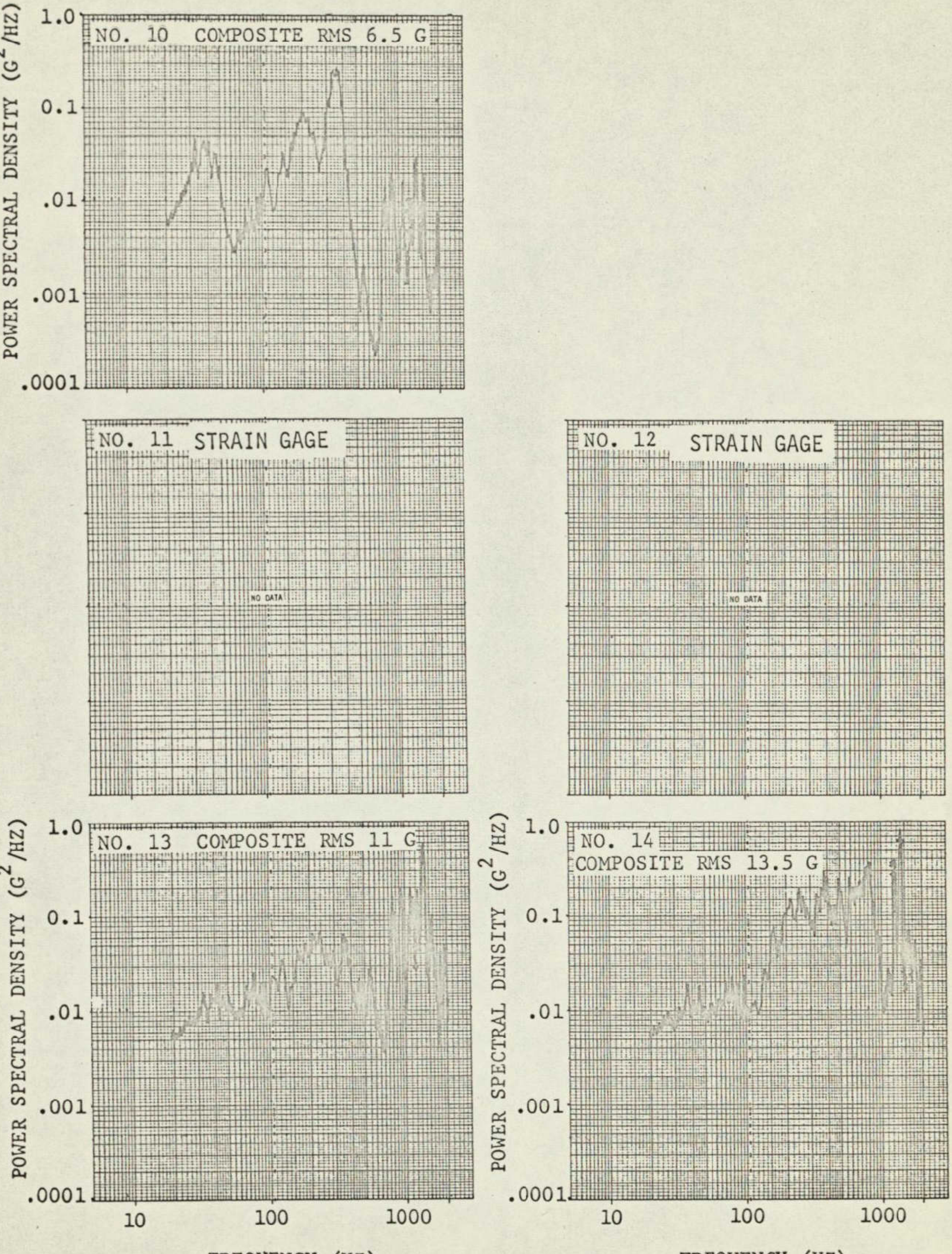


Figure 5-15. Thrust Axis Random Vibration (Sheet 3 of 5)

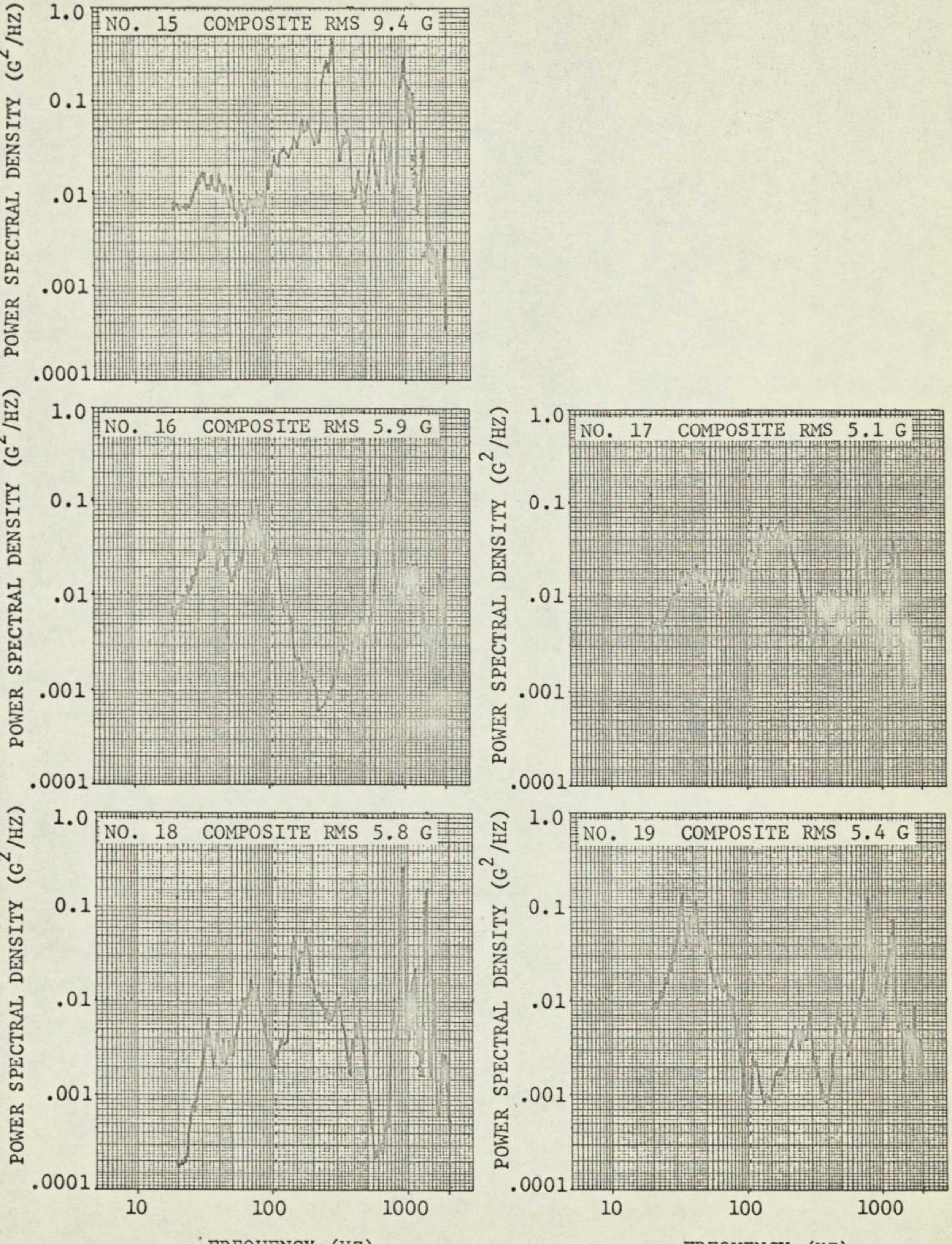


Figure 5-15. Thrust Axis Random Vibration (Sheet 4 of 5)

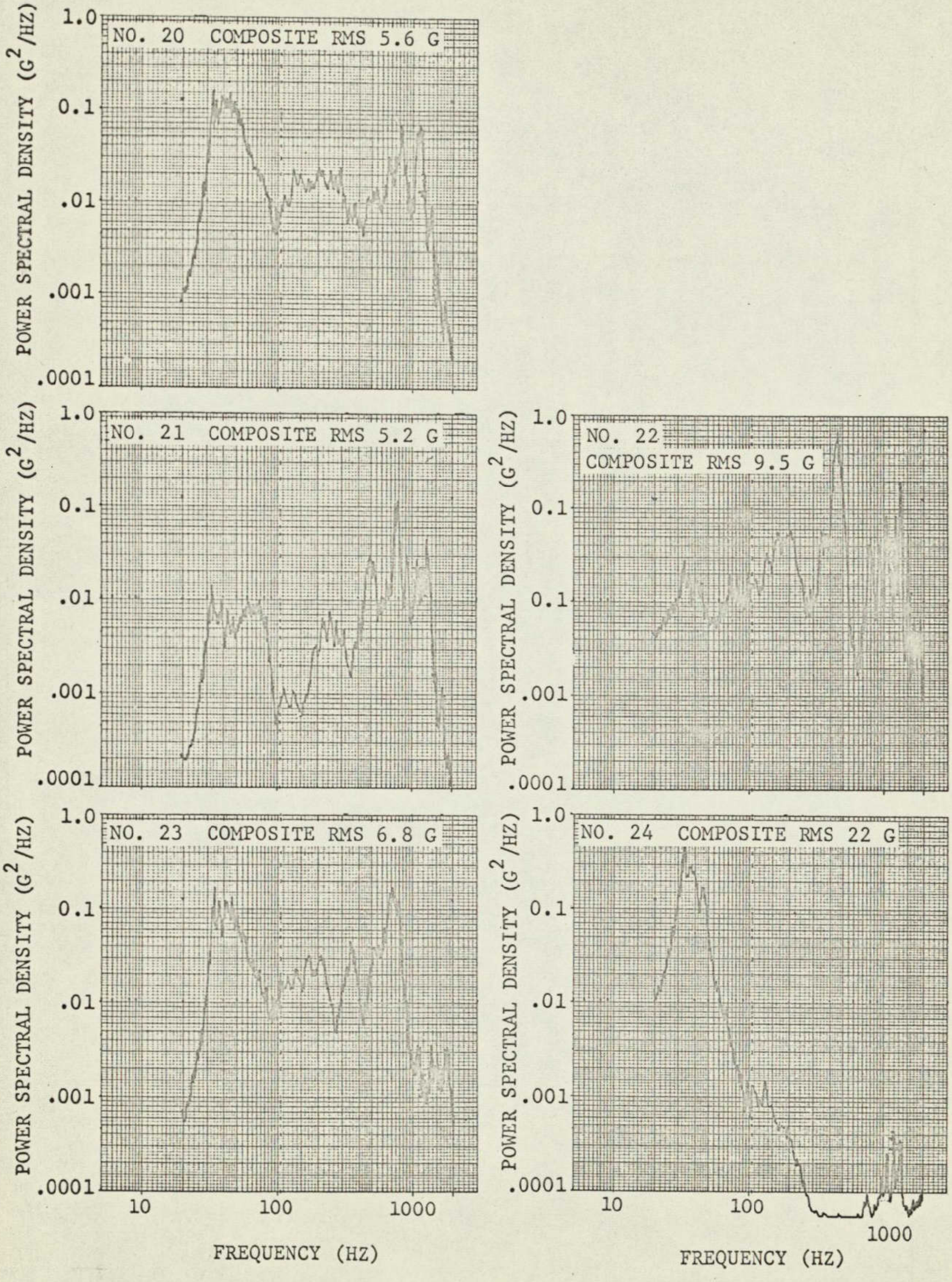


Figure 5-15. Thrust Axis Random Vibration (Sheet 5 of 5)

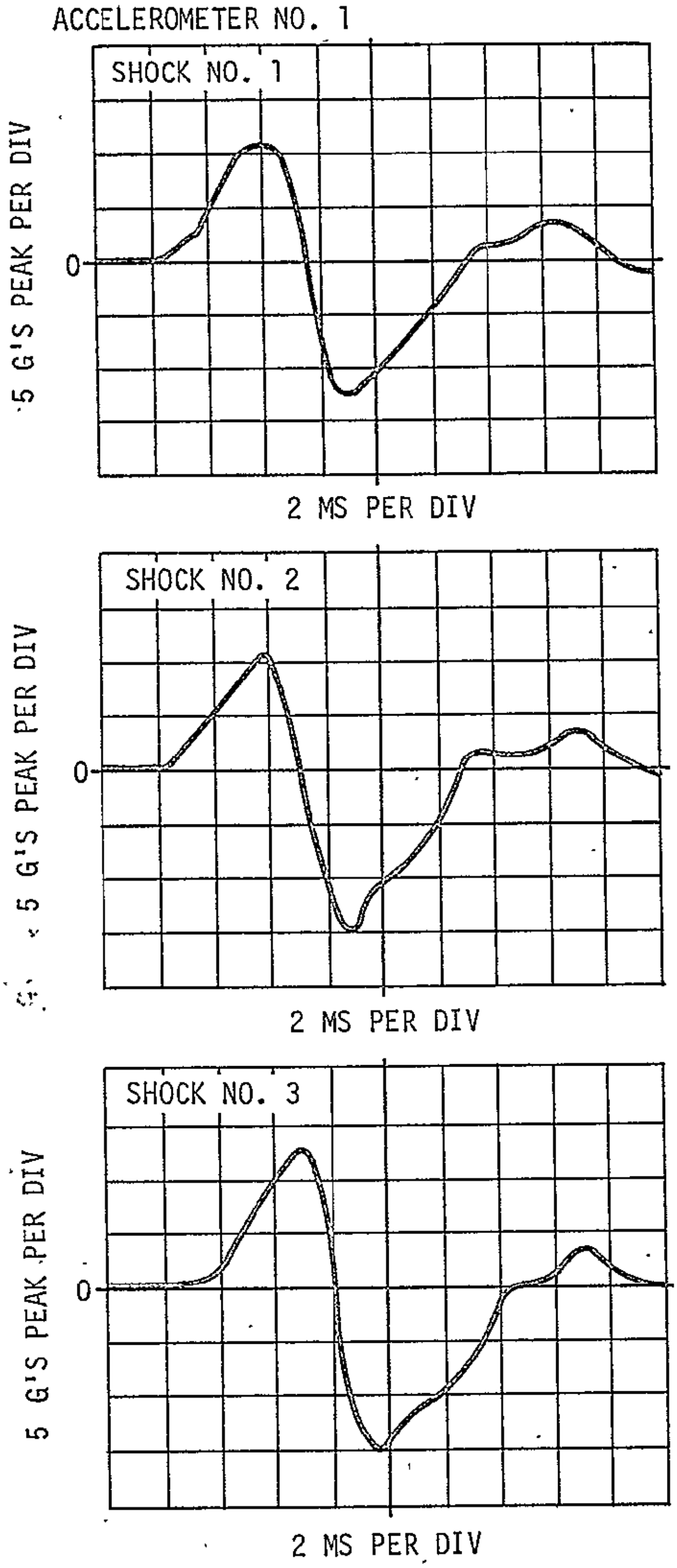


Figure 5-16. Thrust Axis Shock Input

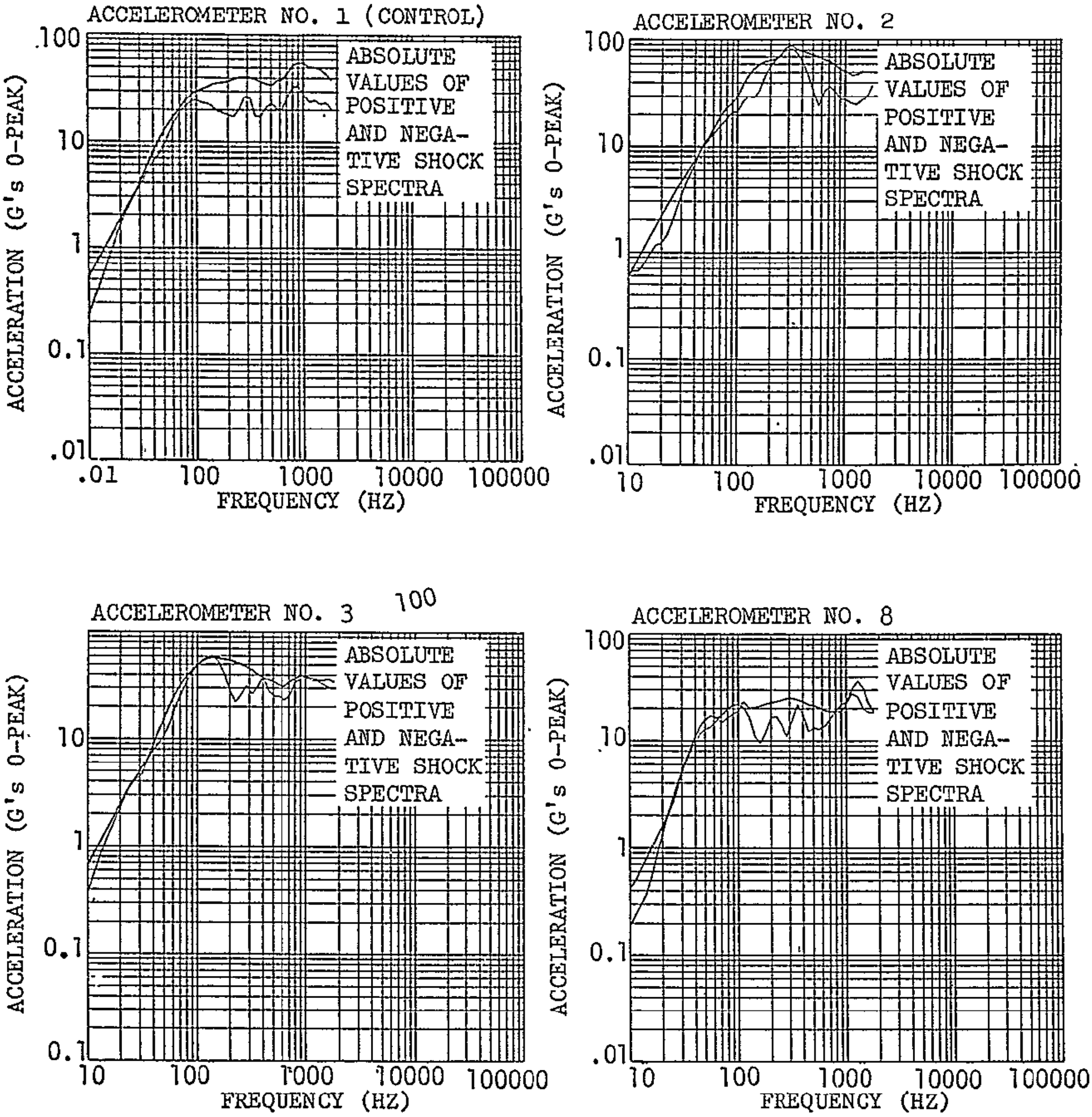


Figure 5-17. Thrust Axis Shock Spectrum (Sheet 1 of 2)

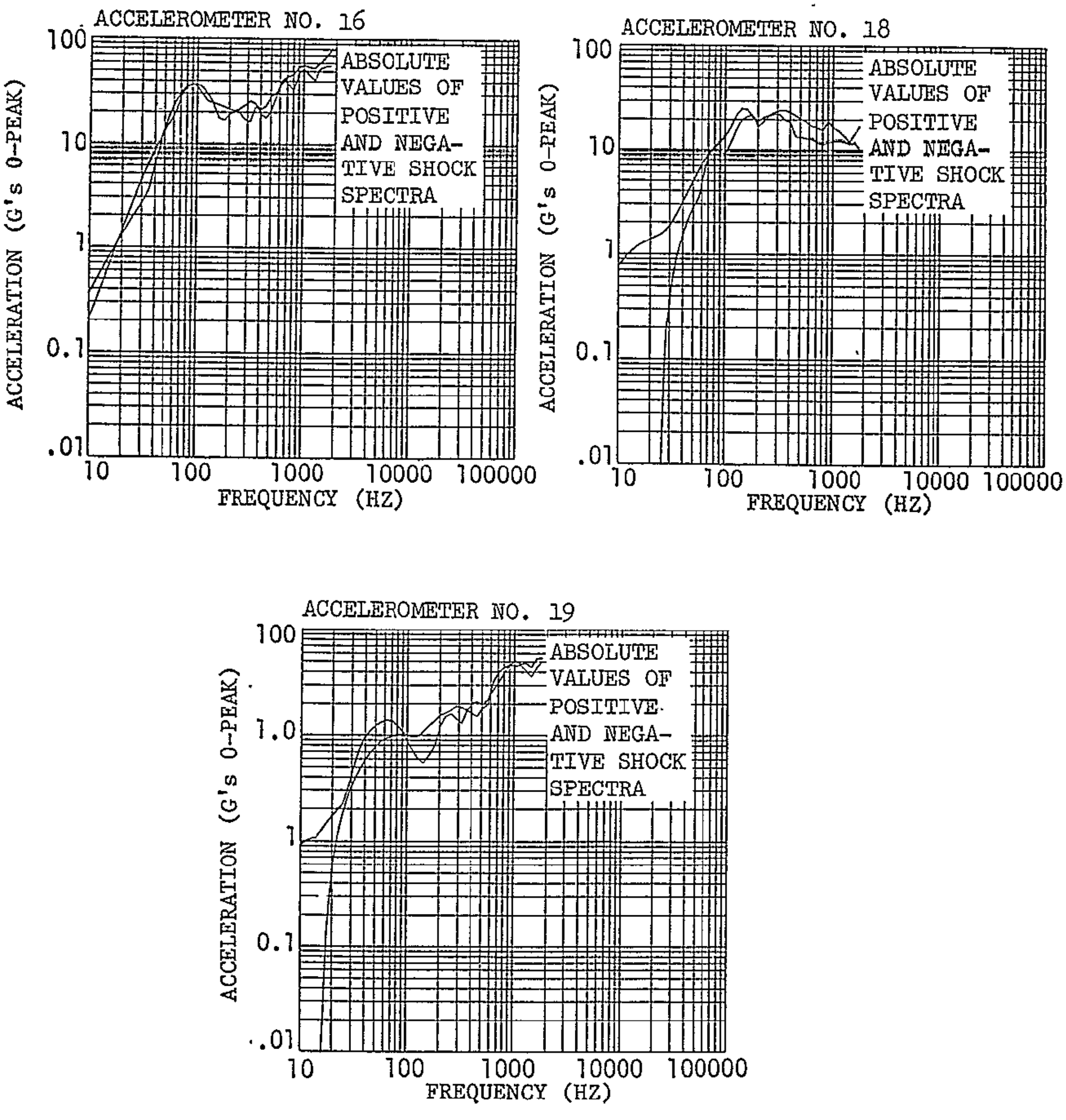


Figure 5-17. Thrust Axis Shock Spectrum (Sheet 2 of 2)

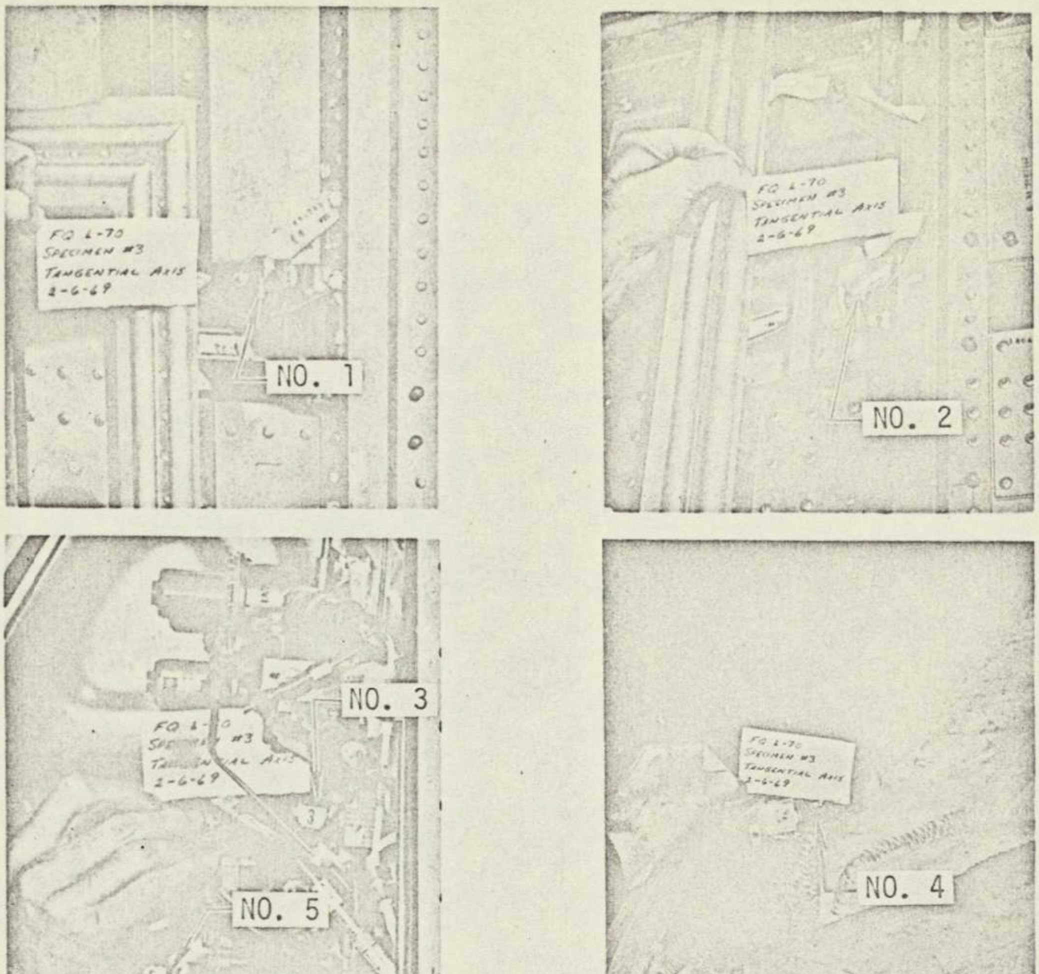


Figure 5-18. Tangential Axis Accelerometer Locations (Sheet 1 of 3)

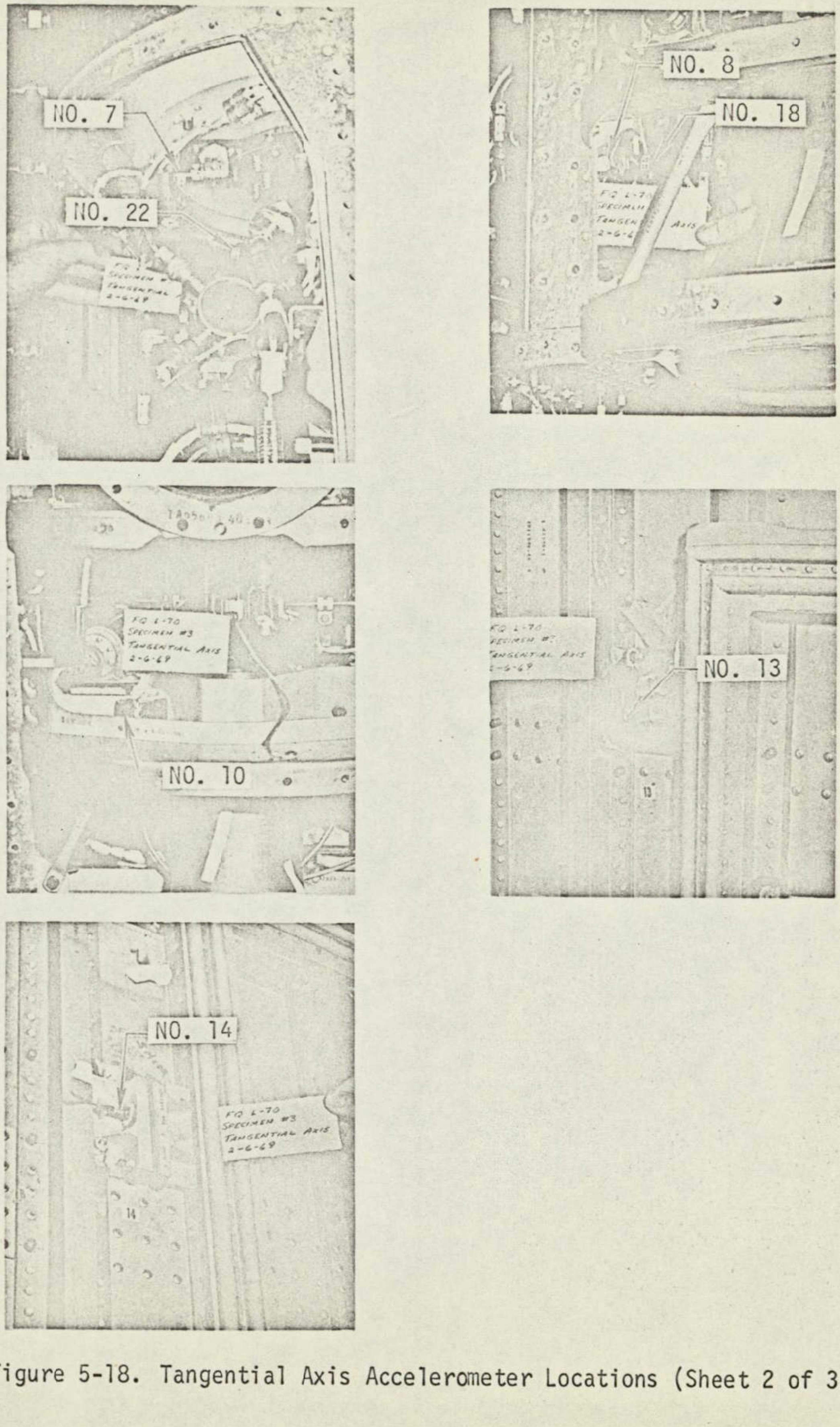


Figure 5-18. Tangential Axis Accelerometer Locations (Sheet 2 of 3)

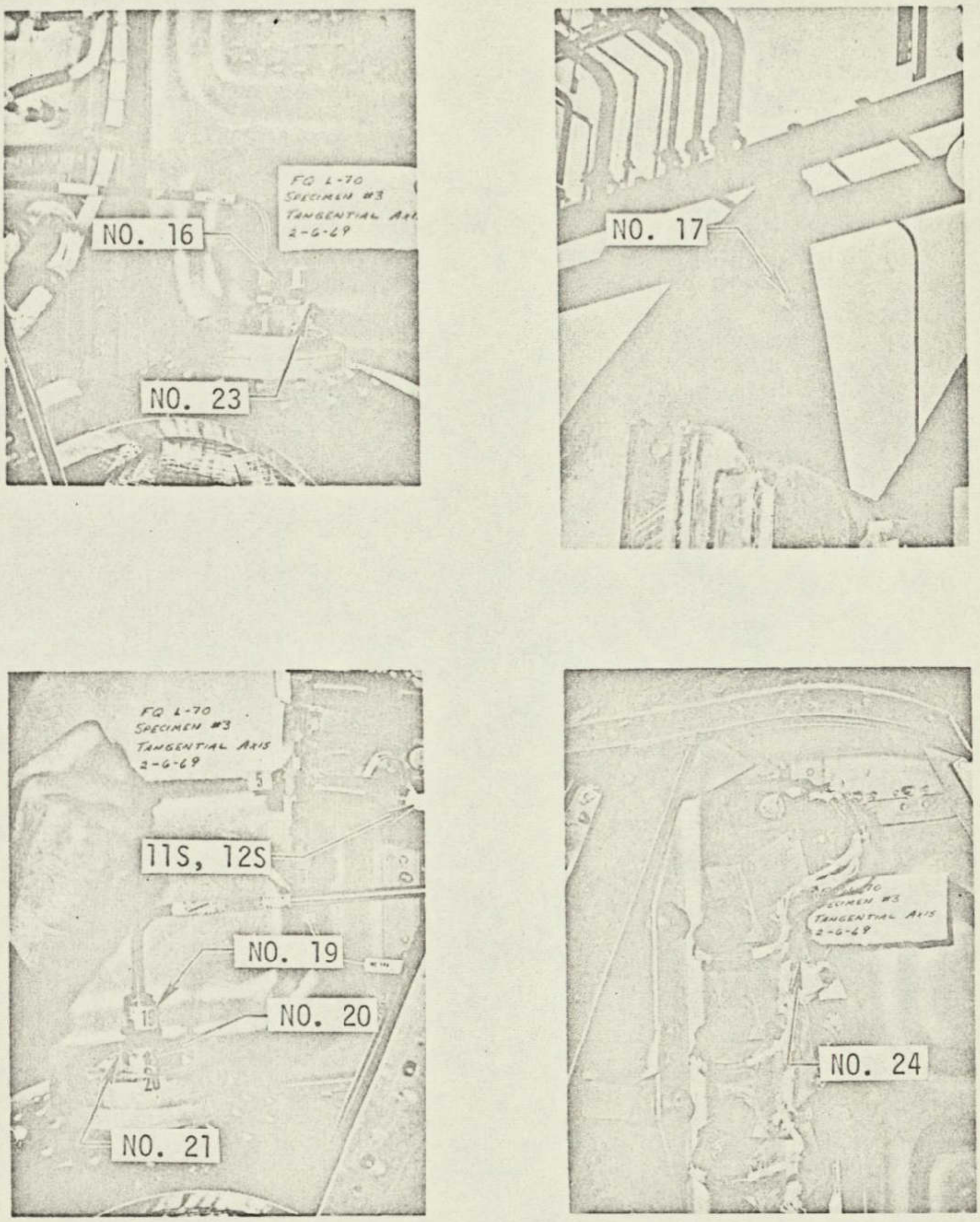


Figure 5-18. Tangential Axis Accelerometer Locations (Sheet 3 of 3)

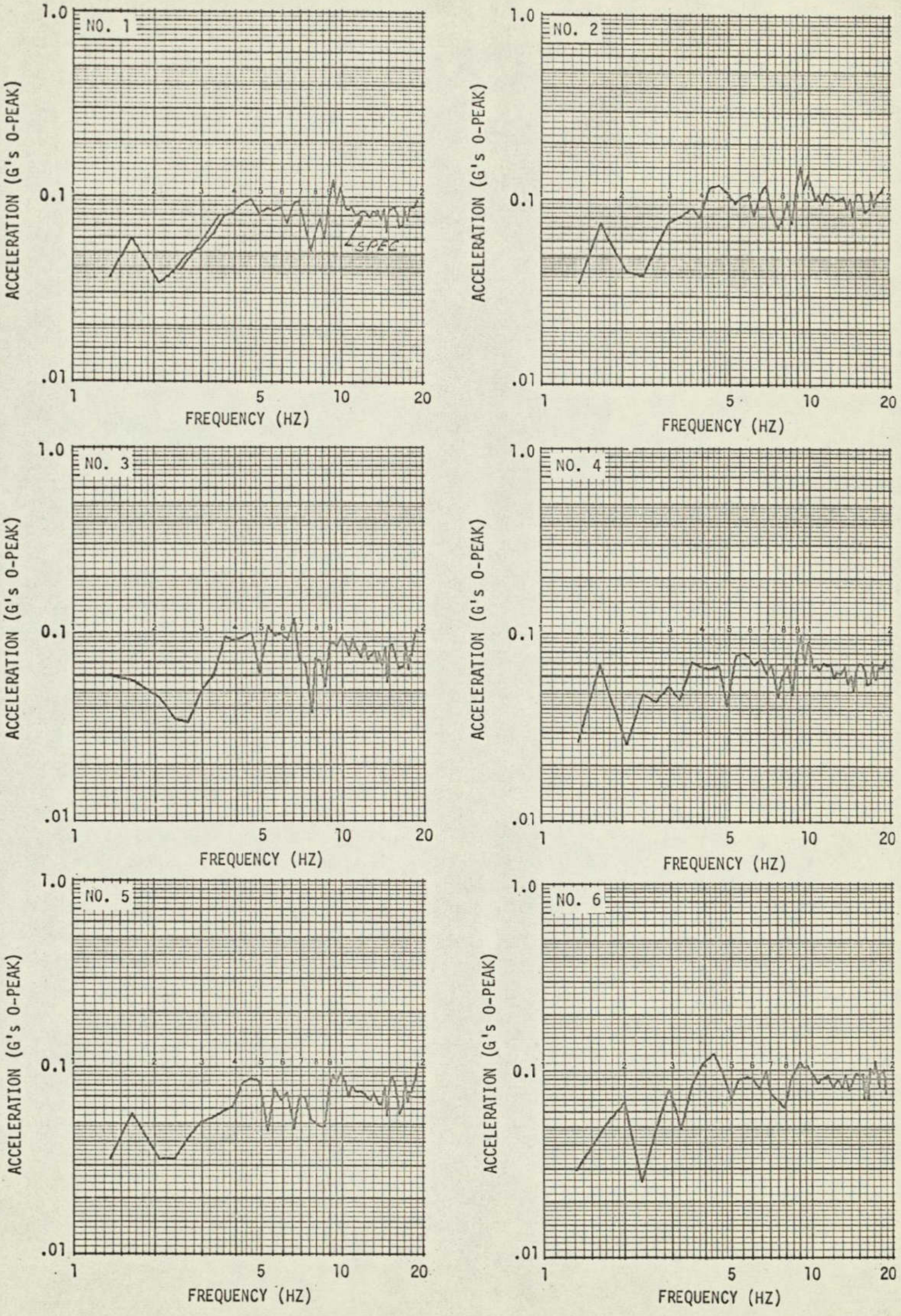


Figure 5-19 Tangential Axis Sinusoidal Sweep (Sheet 1 of 4)

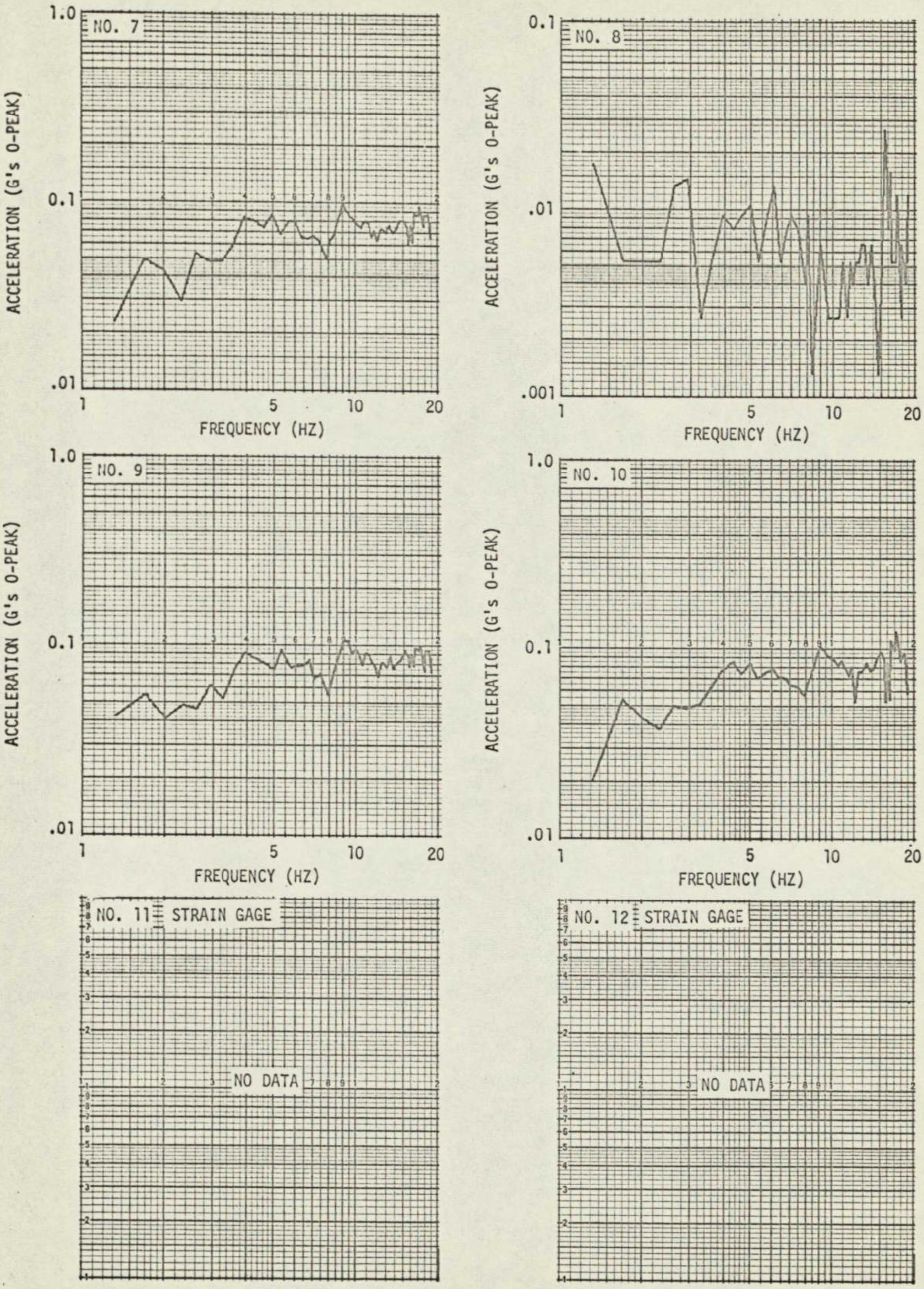


Figure 5-14 Tangential Axis Sinusoidal Sweep (Sheet 2 of 4)

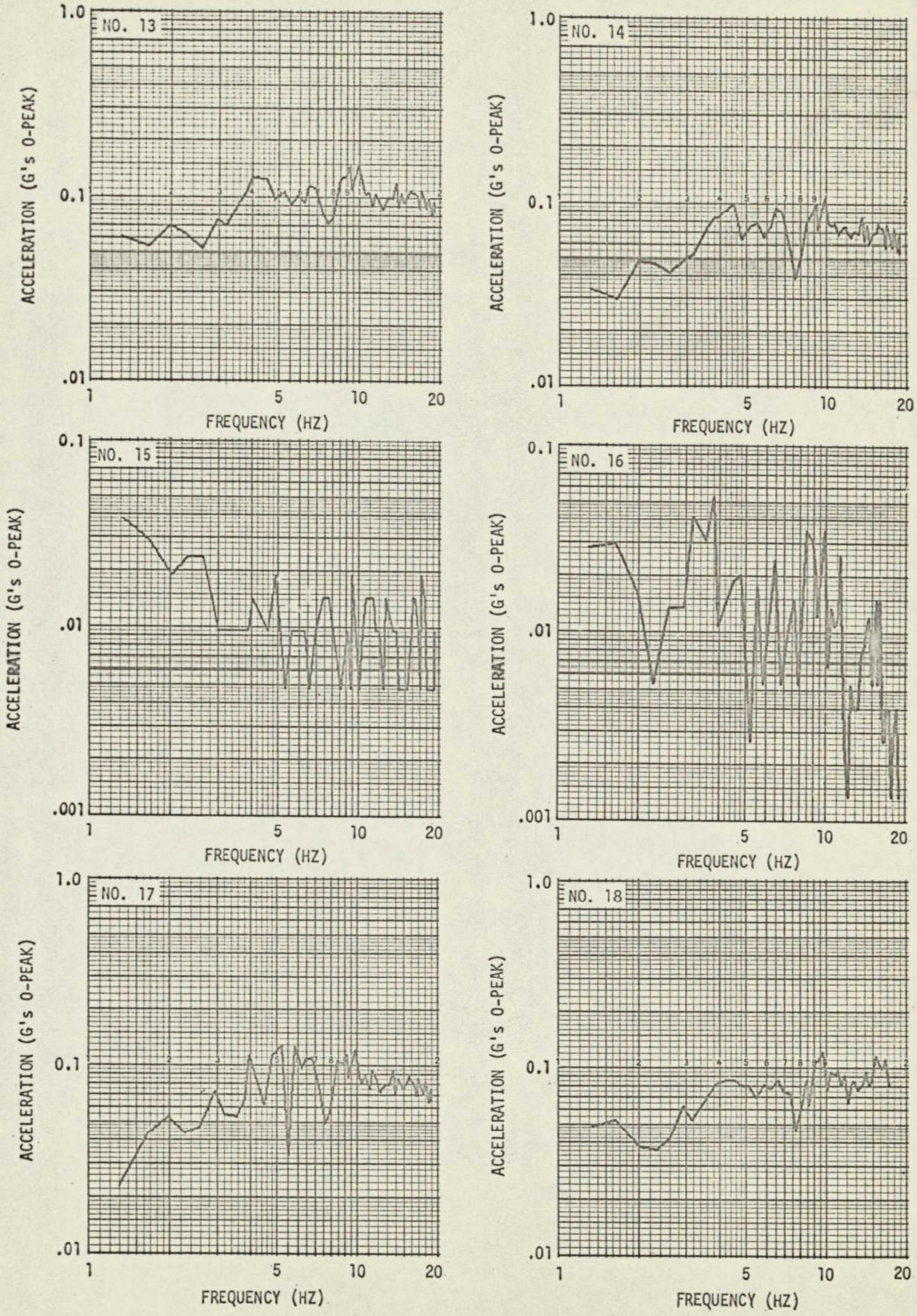


Figure 5-19 Tangential Axis Sinusoidal Sweep (Sheet 3 of 4)

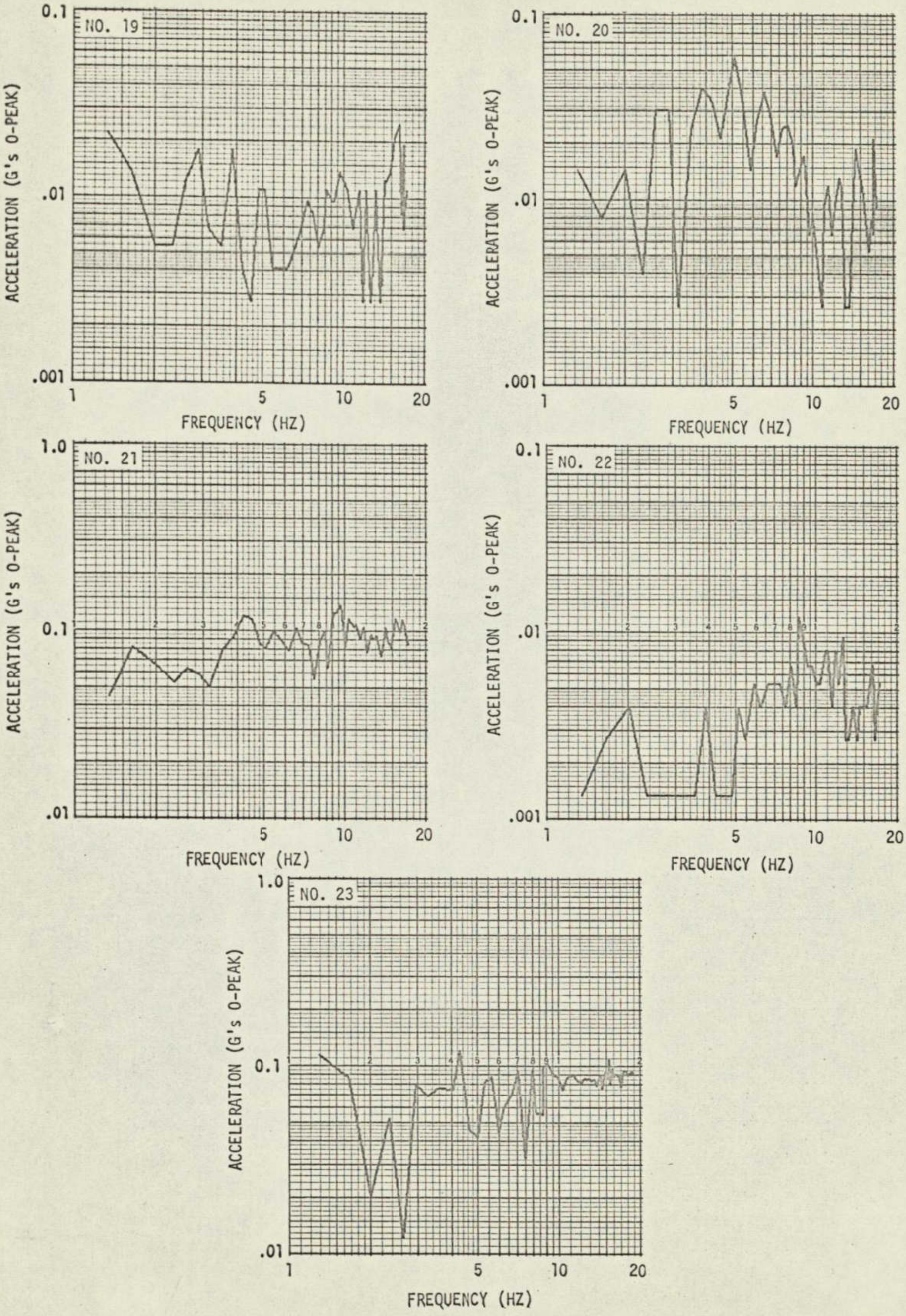


Figure 5-19 Tangential Axis Sinusoidal Sweep (Sheet 4 of 4)

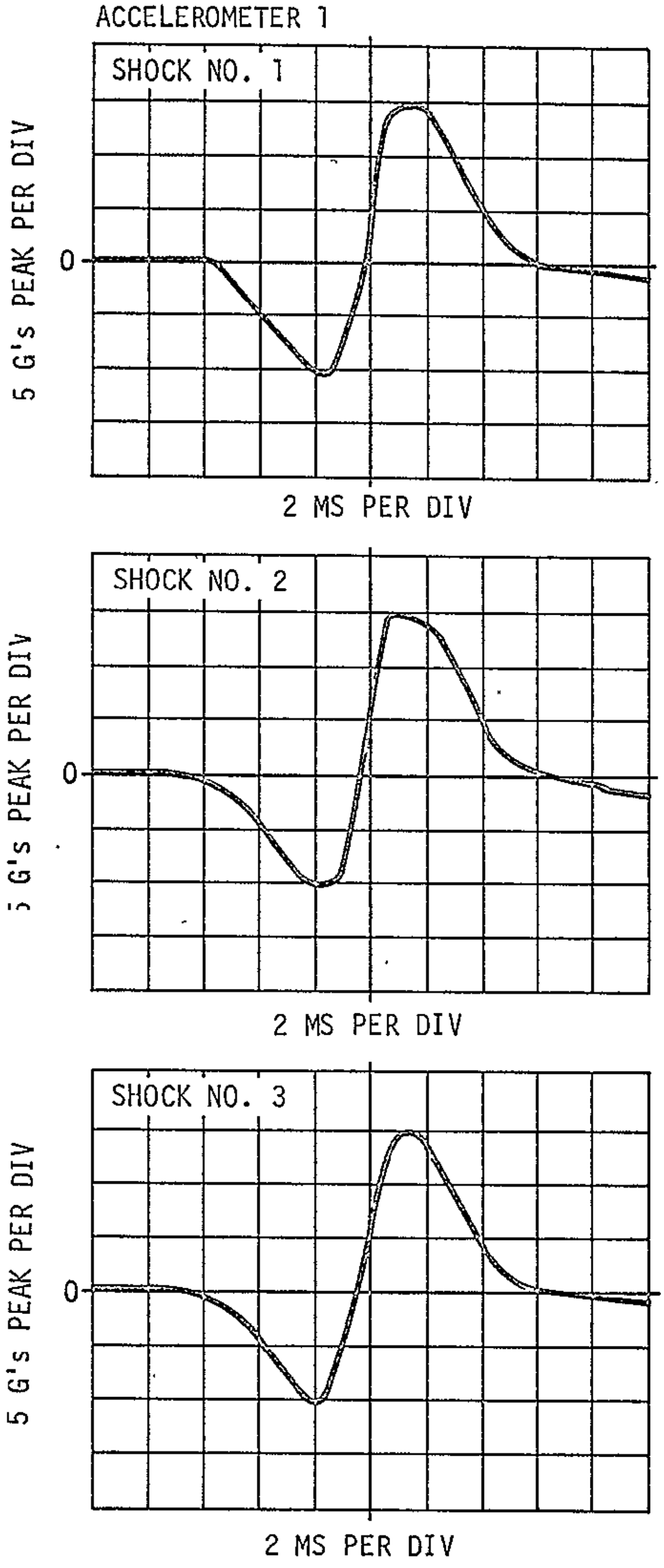


Figure 5-20. Tangential Axis Shock Input

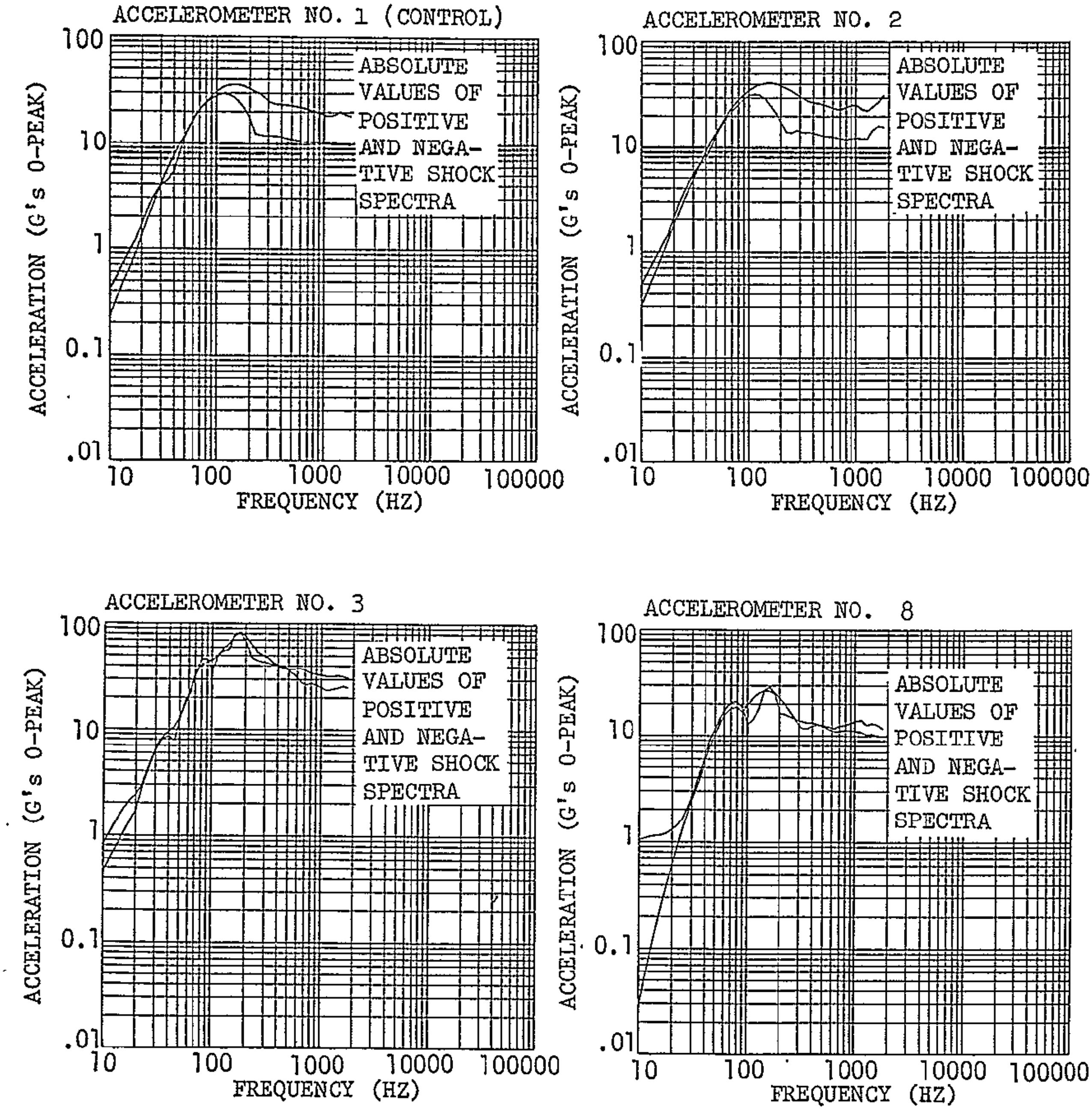
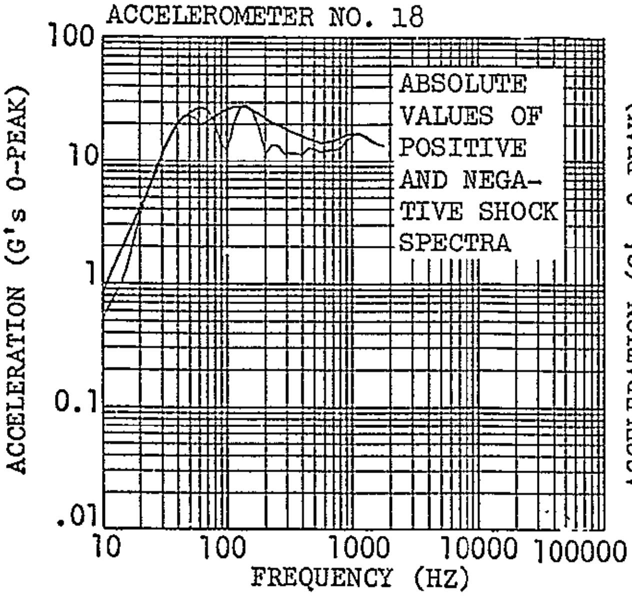
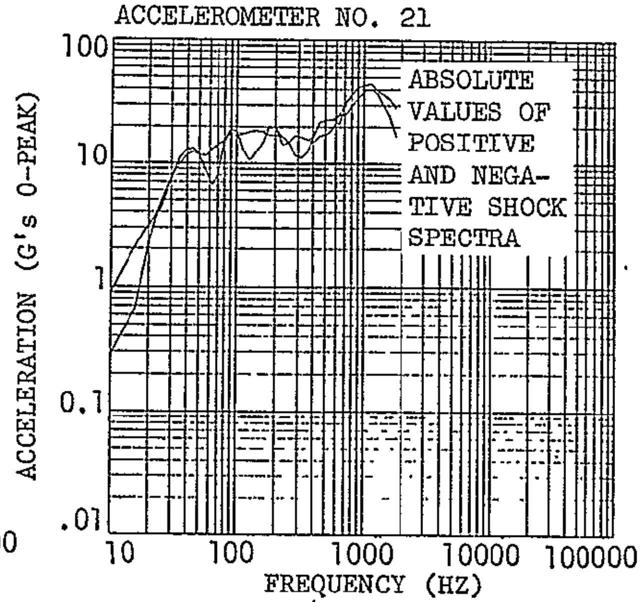


Figure 5-21. Tangential Axis Shock Spectrum (Sheet 1 of 2)





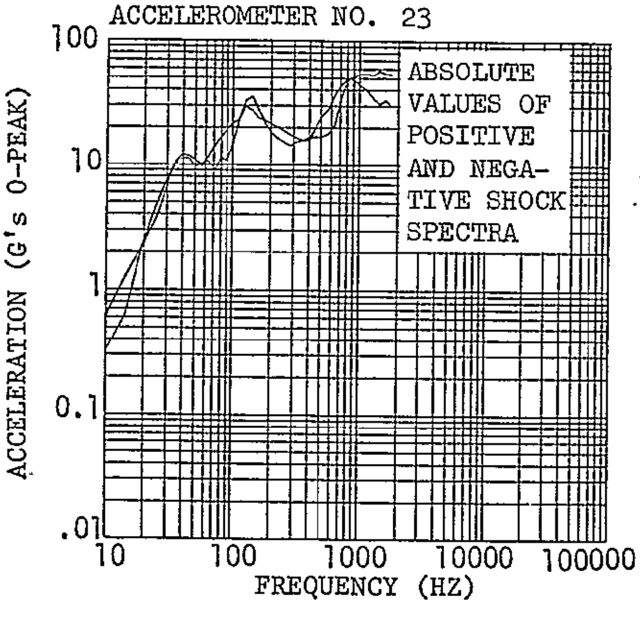


Figure 5-21. Tangential Axis Shock Spectrum (Sheet 2 of 2)

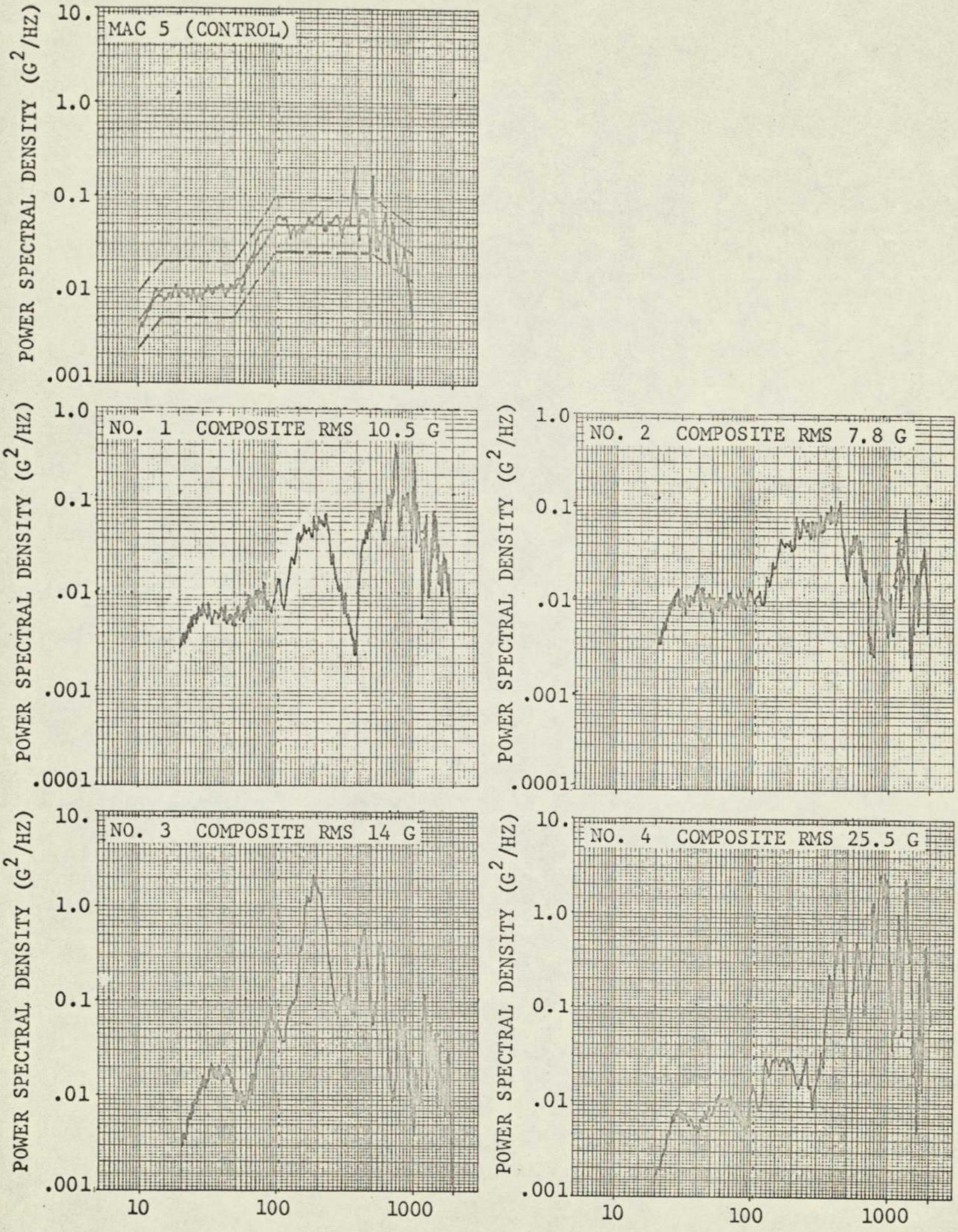


Figure 5-22. Tangential Axis Random Vibration (Sheet 1 of 5)

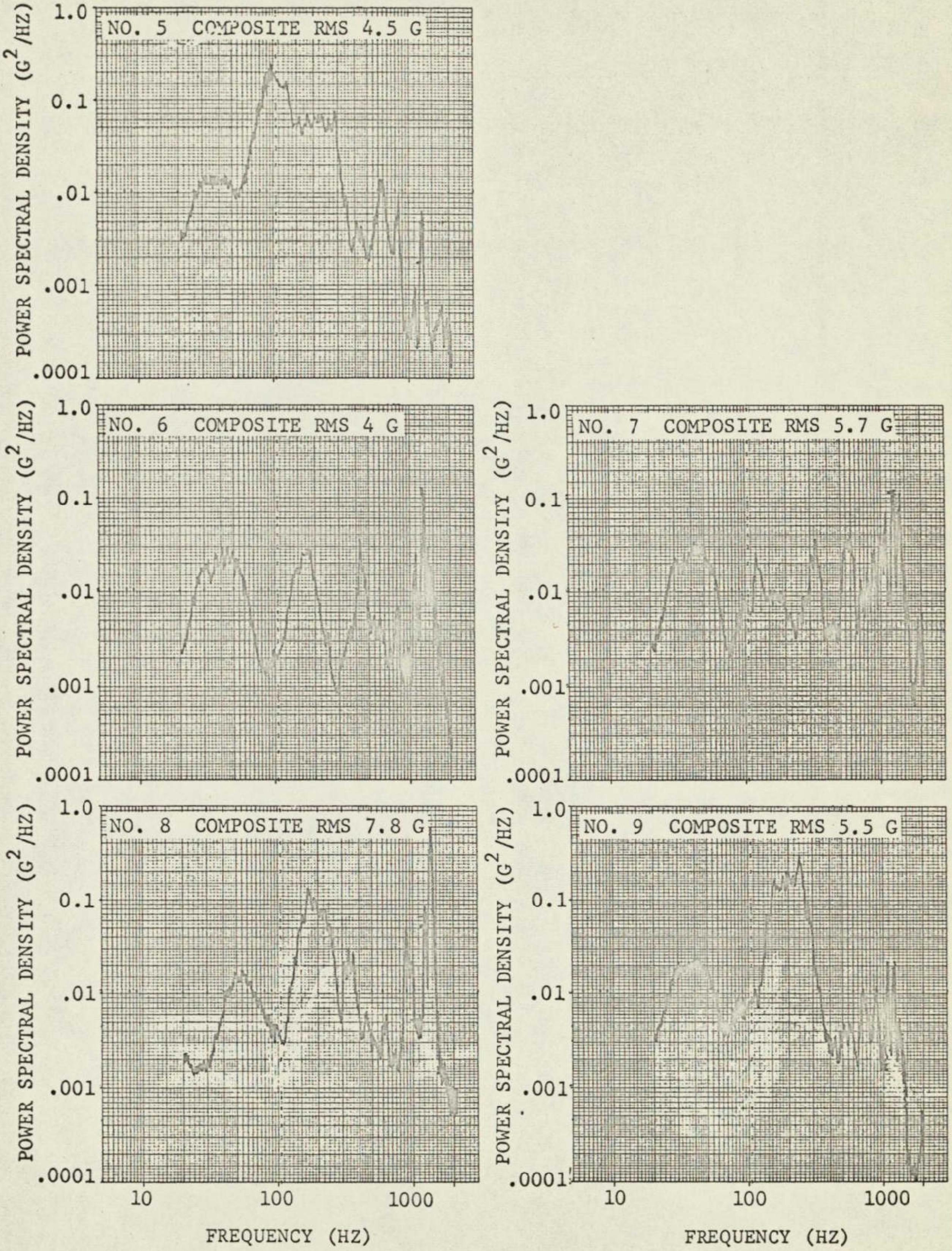


Figure 5-22. Tangential Axis Random Vibration (Sheet 2 of 5)

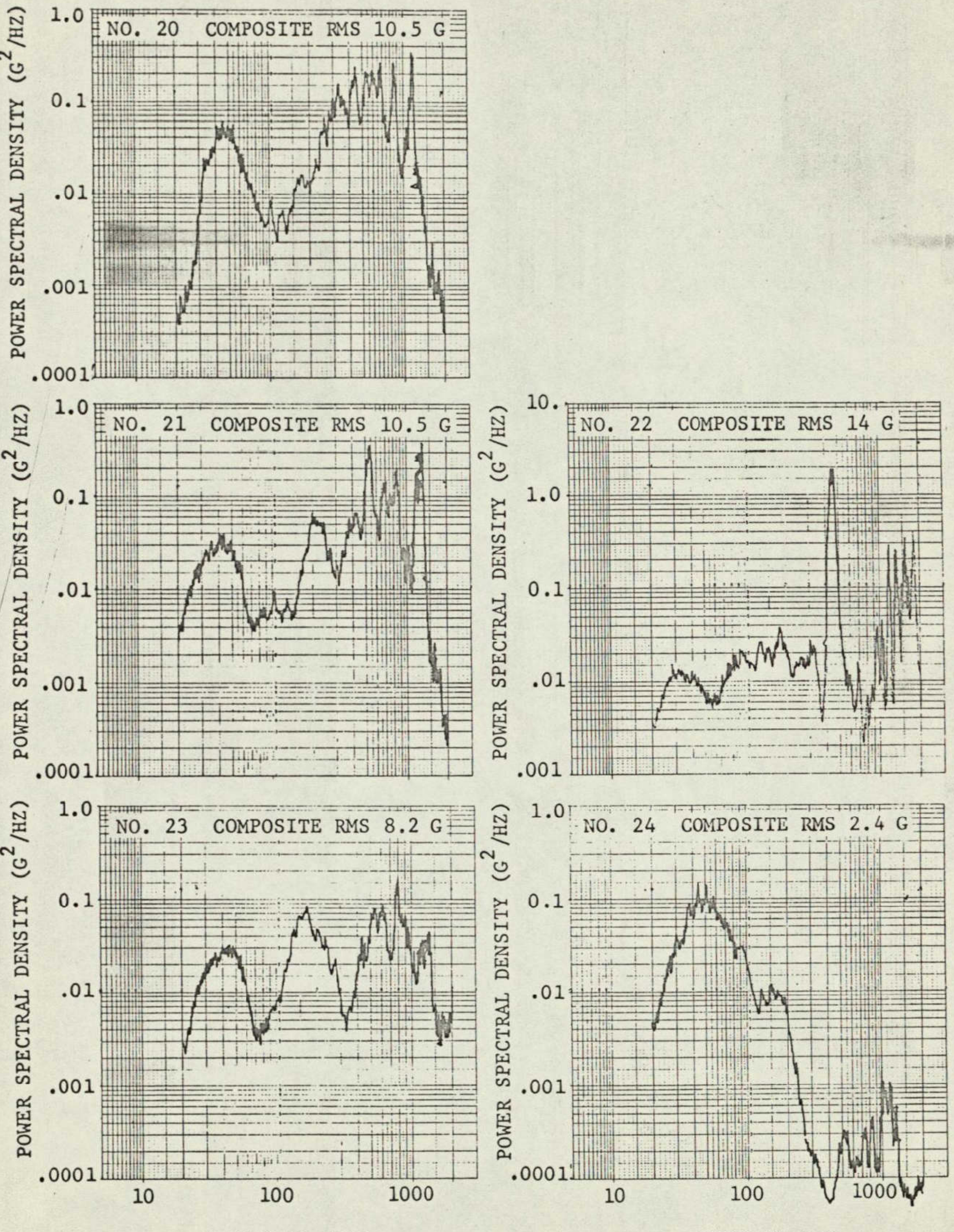


Figure 5-22. Rangential Axis Random Vibration (Sheet 5 of 5)

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Table 4-1
MATRIX OF APPLICATION (Oceanography)

RELATIVE SCALE OF APPLICABILITY
LEGEND
10 HIGH 5 2 LOW

CRITICAL ISSUES | ECONOMIC USES | SOCIAL AND CULTURAL USES | NATIONAL AND INTERNATIONAL USES | KNOWLEDGE OF EVOLUTION | KNOWLEDGE OF STATE | KNOWLEDGE OF CHANGE | EFFECTS ON WEATHER AND CLIMATE | EFFECTS ON DYNAMICS | EFFECTS ON GEOMORPHOLOGY | EFFECTS ON BIOTA

	SELECTED KNOWLEDGE REQUIREMENTS (SKR)	NO
11	DETERMINE FISH POPULATION DISTRIBUTION	01
22	DETERMINE OCEAN BIOTA POPULATION DYNAMICS	02
20	[illegible]	03
32	[illegible]	04
19	[illegible]	05
4	PREDICT WAVE CHARACTERISTICS	06
16	[illegible]	07
3	PREDICT SEA SURFACE WINDS	08
13	DETERMINE AREAS OF UPWELLING	09
6	[illegible]	10
10	[illegible]	11
9	[illegible]	12
5	[illegible]	13
11	[illegible]	14
8	[illegible]	15
15	[illegible]	16
2	[illegible]	17
17	[illegible]	18
16	[illegible]	19
3	[illegible]	20
7	[illegible]	21
14	DETERMINE WATER COLUMN STABILITY	22
9	DETERMINE SUBMARINE VOLCANIC ACTIVITY	23
12	DETERMINE HEAT FLOW ACROSS THE AIR/SEA INTERFACE	24
8	[illegible]	25
13	MONITOR CLOUD PATTERNS	26
13	DETERMINE HUMIDITY OVER THE OCEAN	27
17	[illegible]	28
18	[illegible]	29
9	[illegible]	30
7	DETERMINE ANOMALIES IN THE ELECTROMAGNETIC FIELD	31
3	DETERMINE ANOMALIES IN THE GRAVITY FIELD	32
5	[illegible]	33
19	[illegible]	34
9	[illegible]	35
13	[illegible]	36
4	[illegible]	37
7	[illegible]	38
9	[illegible]	39
12	[illegible]	40
13	[illegible]	41
12	[illegible]	42
11	[illegible]	43
8	IDENTIFY AND MONITOR SHIP OPERATIONS	44
6	LOCATE OBJECT ON OCEAN SURFACE	45
5	[illegible]	46
4	[illegible]	47
12	[illegible]	48
21	[illegible]	49

FOLDOUT FRAME 1

FOLDOUT FRAME 2

Table 4-2 (page 1 of 2)

MATRIX OF APPLICATION (METEOROLOGY)

RELATIVE SCALE OF APPLICABILITY

LEGEND

10-HIGH 5- 2-LOW

CRITICAL ISSUES

ECONOMIC USES: CHEMICAL RESOURCES / ENERGY / COMMERCE AND INDUSTRY / TRANSPORTATION — SOCIAL AND CULTURAL USES: RECREATION / LIFE / EDUCATION / POLLUTION — NATIONAL AND INTERNATIONAL USES: MONITORING / SECURITY / DATA EXCHANGE / RESCUE AND RECOVERY — KNOWLEDGE OF STATE: CHEMICAL / BIOLOGICAL / PHYSICAL

NO	SELECTED KNOWLEDGE REQUIREMENTS (SKR)																																						
51	Determine temperature field	2	5		5	6	2	5			5	2	5			2		5		5	2	2				10							2			5	10		2
52	Determine air motion and vertical acceleration field	2	5	5	10		10	5			2		10		5	2	5	10	2	5	5				8	5							5	5	5	2	10		
53	Determine atmospheric composition and mass field	5	2	10			2		5		2					2		5	5		5					5					10	10				2	2	5	5
54	Determine water vapor distribution	5	2		5	5			2	2		2				2		5		2	5					5		2					5	5		5	10	5	5
55	Determine ozone distribution			2		5			2					2			2	5	10												10								5
56	Determine aerosol, particles, sources, types and extent	5	5		2	2										2			5		2	2				2									10	2		10	2
57	Determine energy exchange	5	5		10	10														2		2				5											5		10
58	Determine momentum exchange	5	5		5		2													2						5											5		5
59	Determine diffusion properties in the atmosphere		2		2		5	5	2							2	5	10	2	2													2					2	
60	Determine evaporation/condensation distribution	10	10		10									2		2				2		5				5											5	2	5
61	Determine radiative properties of the atmospheric layers and boundaries	2	2		2	10				2		2		5		2				5	10							2	5	5	2					5	5	2	10
62	Determine heat sources and sinks	5	5		5	10	2			2	2	2	5				2	5		5						5		2								5	5		5
63	Determine spectral distribution of solar radiation					10				5		5																5								5		2	
64	Determine global heat balance	2			2	10																				5											2		5
65	Determine the radio propagation characteristics of the atmosphere									10		10				2												10								5			2
66	Determine acoustic propagation characteristics of the atmosphere															2																				5			2
67	Determine extent and temperature gradients of stable layers	5	10		5		5	5		10	5		5		5			10	10	10	5					5		10								5	5		2
68	Determine extent of small scale turbulence/turbulence	2	2		2		5	5	2		5		5		2	2		5	2	2																5	2		2
69	Determine cloud patterns	10	10			10					2					2					5	5			5	10			2	2							5	2	5
70	Determine cloud type, height, thickness and [illegible]	10	10		5	10				2	5	2	5		2	2		5	5	2	5	5			5	10	5	2	5	5							5		5
71	Determine cloud motion and life	10	10		5						2		5			2		5	2		5	5			5	10			2	2							5	2	5
72	Determine cloud droplet and ice crystal size distribution	10	10			5																10				2										2	2	2	5
73	Determine precipitation extent, type and intensity	10	10		5		5	5	2		2							10	10	10	5	10			5	5	10		2	2			5	6		2	5	5	2
74	Determine pollution sources and extent	2	2	5		5	10	10	5					5		2	10	10	10	10	10						5								5			5	2
75	Locate and track airborne objects										5		2																10	5			2		2		2	6	
76	Locate jet streams	2	2								5				2										5	5													5
77	Locate areas of fog, smog and CAT		5			2					10		5		5	2						2			10	5			2	2							2	2	2
78	Locate and track severe local storms (thunderstorms, tornadoes, dust storms, etc.)	5	2							5	5	5			5			5	2		10	2			5	10	10	5	2	2							2	5	2
79	Locate and monitor large scale circulations	2	2	2	2		2	5	2		2		5					5	5	2	2				2	2							2	2	2		2	2	2
80	Locate and monitor hurricanes	5	2		5																	2				5	10										2		2
81	Locate and monitor forest fires				2												5	5			5																	2	
82	Determine ice and snow cover	5			2	5					2															2				2						2			5
83	Determine surface water area, extent, and state	10			2	10																5														2	5	5	5
84	Locate and track surface objects																												10	10									
85	Determine general circulation changes	2	2		5						2		2					5			5	2			10	10							5	5	5		5		5
86	Determine climate changes															2			2			2																2	
87	Determine land use distribution patterns and surface characteristics	2				5							2				2																			2		2	
88	Monitor volcanic activity	2															5	5			5										2						2	2	
89	Monitor land erosion/sedimentation	2				2											5				2						2											2	
90	Monitor man-made and natural explosions				2	2				5		5					5				5							5			2						2	2	
91	Determine atmospheric characteristics of other planets					2																															2		
92	Determine electric field									5	2			2		2				2								5								10			
93	Monitor upper atmospheric phenomena			2						5		5			5	5												2			5	5				5			2

FOLDOUT FRAME 1

FOLDOUT FRAME 2

Table 4-2 (page 2 of 2)
MATRIX OF APPLICATION (METEOROLOGY)

KNOWLEDGE OF CHANGE — Transformations of Momentum / Transformations of Heat / Transformations of Mass / Transformations of Composition / Prediction - Short Range / Prediction Extended Range / Prediction Long Range / Non-Large Scale / Non-Small Scale

EFFECTS ON CLIMATE — Macro Scale / Meso Scale / Micro Scale

EFFECTS ON RESOURCES — Land / Plants / Livestock

EFFECTS ON LIFE AND PROPERTY — Commercial / Civil / Transportation / Human Life

Total	Selected Knowledge Requirements (SKR)	No.
65	Determine temperature field	51
74	Determine air motion (direction, acceleration) field	52
37	Determine atmospheric composition and mass (pressure field)	53
55	Determine water vapor distribution	54
23	Determine ozone distribution	55
47	Determine aerosols, particles, sources, types, and extent	56
29	Determine energy exchange	57
18	Determine momentum exchange	58
29	Determine diffusion properties in the atmosphere	59
43	Determine evaporation/condensation distribution	60
50	Determine radiative properties of the atmosphere, layers and boundaries	61
31	Determine heat sources and sinks	62
24	Determine spectral distribution of solar radiation	63
20	Determine global heat balance	64
11	Determine the radio propagation characteristics of the atmosphere	65
3	Determine acoustic propagation characteristics of the atmosphere	66
28	Determine extent and temperature gradient of stable layers	67
26	Determine extent of small scale turbulence	68
39	Determine cloud patterns	69
54	Determine cloud type, height, thickness, and density	70
33	Determine cloud motion and life	71
29	Determine cloud condensation and ice nuclei distribution	72
55	Determine precipitation extent, type and intensity	73
35	Determine pollution sources and extent	74
20	Locate and track airborne objects	75
13	Locate jet streams	76
33	Locate areas of fog, icing, and CAT	77
39	Locate and track severe local storms (thunderstorms, tornadoes, dust storms, etc.)	78
42	Locate and monitor local circulations	79
29	Locate and monitor hurricanes	80
14	Locate and monitor forest fires	81
30	Determine ice and snow cover	82
38	Determine surface water area, extent and state	83
2	Locate and track surface objects	84
31	Determine general circulation changes	85
33	Determine climate changes	86
39	Determine land use distribution patterns and surface characteristics	87
14	Monitor volcanic activity	88
24	Monitor land erosion/sedimentation	89
11	Monitor man made and natural explosions	90
2	Determine atmospheric characteristics of other planets	91
24	Determine electric field	92
20	Monitor upper atmospheric phenomena	93

Table 4-3
SELECTED KNOWLEDGE REQUIREMENTS (Oceanography)

MEASUREMENT REQUIREMENTS	01 DETERMINE FISH POPULATION DISTRIBUTION	02 DETERMINE OCEAN BIOTA POPULATION DYNAMICS	03 DETERMINE AREAS OF TIDAL ACTION	04 DETERMINE OCEAN CURRENT DISTRIBUTION	05 DETERMINE OCEAN SURFACE ROUGHNESS (SEA STATE)	06 PREDICT WAVE CHARACTERISTICS	07 DETERMINE NEAR SURFACE WIND DISTRIBUTION	08 PREDICT SEA SURFACE WINDS	09 DETERMINE AREAS OF UPWELLING	10 DETERMINE ENERGY EXCHANGE ACROSS THE AIR/SEA INTERFACE	11 DETERMINE MOMENTUM FLUX AT THE AIR/SEA INTERFACE	12 DETERMINE AREAS OF CONVERGENCE OR DIVERGENCE	13 DETERMINE CHANGES IN MEAN SEA HEIGHT	14 MONITOR LAND EROSION/ACCRETION AT THE LAND/SEA INTERFACE	15 DETERMINE AREAS OF POTENTIAL TURBIDITY CURRENTS	16 DETERMINE BREAKER AND SURF CHARACTERISTICS	17 DETECT AND MONITOR TSUNAMIS	18 DETERMINE INTERNAL WAVE CHARACTERISTICS	19 DETERMINE BOTTOM TOPOGRAPHY	20 LOCATE OIL AND MINERALS	21 DETERMINE DISTRIBUTION OF OCEAN SURFACE CHARGE	22 DETERMINE WATER COLUMN STABILITY	23 DETERMINE SUBMARINE VOLCANIC ACTIVITY	24 DETERMINE HEAT FLOW ACROSS THE AIR/SEA INTERFACE	25 DETERMINE LOWER ATMOSPHERE STABILITY
SEA COLOR	5	5		2	2				5			2				5			5	2			2		
TURBIDITY	2	5		2					2	2		2		2								2			
BIOLUMINESCENCE	5	5							2																
CLOUD PATTERNS	2	2					5	5	5	2	2	5												5	5
COASTLINE PATTERNS			5						5		2	5		10	5	5	5		2	5			2		
STORM TRACKING			2	2	2	5		5	5	2	2	5		2	5	5		2							5
SEA SURFACE TEMPERATURE	10	(5)		5				2	10	5		5						5					5	5	5'
SEA TEMPERATURE VERTICAL PROFILE	5	5		5					2	5	2		5					5				10		10	
HEAT FLOW										10												2	5	10	5ı
ATMOSPHERIC VERTICAL TEMPERATURE PROFILE (LOW LEVELS)					2	2		2		5	2													·10	10
ATMOSPHERIC MOISTURE PROFILE (LOW LEVEL)										5														5	5
ATMOSPHERE COLOR										2													2		5
SURF PATTERNS			5		2									5	2	10			2	2					
PRECIPITATION PATTERNS										5														2	
WAVE HEIGHT					10	5		2		5	5					2		2				2			
WAVE PERIOD					10	5	5	2		5	5					2		2				2			
WAVE DIRECTION					5	5	5	2		·2	5					2		2				2			
SURFACE WIND			2	5	5	10	10	10		5	5	5				2		2							2
VERTICAL WIND PROFILE				2	2	5	5	5		5	10	2									2			5	5
CHANGE IN MEAN SEA HEIGHT			5	5								5	10				10	5							
WAVE PATTERNS					5	5	5	5		2	2	2		2		5									2
GLITTER PATTERNS					5		5	2			2														
SLICK PATTERNS	2	5					5	2	5	2	2	5						5		5				2	
DEPTH PROFILE			5											2	10	2	5		10	5			5		
LOCATE AND TRACK SURFACE/SUBSURFACE OBJECTS	2																								
SALINITY	2	2							2				2												
ACOUSTIC SIGNATURE	5				2																				
MIXED LAYER DEPTH	5	2			2				2		2	2										5			
MEASURE CURRENT				10	2					5	5	5	5	5	2		5	5							
BAROMETRIC PRESSURE			2	2			5	5					2												
SPECTRAL ANALYSIS (ABSORPTION/EMISSION SIGNATURES)	2	·5																							
GRAVITATIONAL ANOMALIES																			2	5			2		
MAGNETIC ANOMALIES																				5	2				
BOTTOM COMPOSITION															5				2				5		
SURFACE CHARGE				2						2											10		2		

MEASUREMENT REQUIREMENTS	26 MONITOR CLOUD PATTERNS	27 DETERMINE HUMIDITY OVER THE OCEAN	28 MONITOR LOW LEVEL ATMOSPHERIC TURBULENCE	29 MONITOR HURRICANE AND TYPHOON FORMATIONS	30 TRACK STORM PATHS	31 DETERMINE ANOMALIES IN THE ELECTROMAGNETIC FIELD	32 DETERMINE ANOMALIES IN THE GRAVITY FIELD	33 LOCATE SLICKS	34 DETERMINE TEMPERATURE DISTRIBUTION	35 DETERMINE MIXED LAYER DEPTH	36 DETERMINE AREAS OF EVAPORATION AND CONDENSATION	37 DETECT AND MONITOR SEA ICE AND ICEBERGS	38 PREDICT FOG (HORIZONTAL VISIBILITY)	39 DETERMINE SHORELINE GEOMORPHOLOGY	40 DETERMINE CHEMICAL COMPOSITION DISTRIBUTION	41 DETERMINE SEWAGE AND INDUSTRIAL WASTE COMPOSITION AND DISPERSION	42 DETERMINE COMPOSITION OF BOTTOM SEDIMENTS	43 DETERMINE NUTRIENT DISTRIBUTION	44 IDENTIFY AND MONITOR SHIP OPERATIONS	45 LOCATE OBJECTS ON OCEAN SURFACE	46 LOCATE AND IDENTIFY OBJECTS BENEATH OCEAN SURFACE	47 DETERMINE AEROSOL PARTICLE DISTRIBUTION	48 DETERMINE AREAS OF SMALL SCALE OCEAN TURBULENCE	49 DETERMINE TRANSMITTANCE PARTICLE DISTRIBUTION	NUMBER OF OCCURRENCES
SEA COLOR								5				5		5	2	2	2	5						5	18
TURBIDITY															2	5		5					2	2	13
BIOLUMINESCENCE								2								2		5	2						7
CLOUD PATTERNS	10		5	5	5				2		2		5ı												17
COASTLINE PATTERNS						2	5							10		5									15
STORM TRACKING	5		5	5	10	2			2		2		5												22
SEA SURFACE TEMPERATURE	5	5	5	5				5	10		2	5	5ı			2	2		5						23
SEA TEMPERATURE VERTICAL PROFILE									5	5					2	2		5		5		5	2		·18
HEAT FLOW	5		5	5				2	2		5	5													12
ATMOSPHERIC VERTICAL TEMPERATURE PROFILE (LOW LEVELS)	5	2	5	5					2		5		5'												14
ATMOSPHERIC MOISTURE PROFILE (LOW LEVEL)	5	10	5	5					2		5		5									5			10
ATMOSPHERE COLOR	5																					5			5
SURF PATTERNS														5								2	2		10
PRECIPITATION PATTERNS	5	5									5		5												6
WAVE HEIGHT				2	2																				11
WAVE PERIOD				2	2																				11
WAVE DIRECTION				2	2																				11
SURFACE WIND	5	5	2	10	10					5	2		5									5	5		22
VERTICAL WIND PROFILE	2	5	10	2							5		5												16
CHANGE IN MEAN SEA HEIGHT				2	2																				8
WAVE PATTERNS			2	5	5											5			5		2		2		16
GLITTER PATTERNS			2					5				2													7
SLICK PATTERNS								10	2							5		5	5		2				17
DEPTH PROFILE						2	5							5		5									12
LOCATE AND TRACK SURFACE/SUBSURFACE OBJECTS												10							10	10	10				5
SALINITY															5	2		5						2	8
ACOUSTIC SIGNATURE			2																5				2		5
MIXED LAYER DEPTH										10													2		9
MEASURE CURRENT									5							5		2					5		14
BAROMETRIC PRESSURE	2			5	10																				8
SPECTRAL ANALYSIS (ABSORPTION/EMISSION SIGNATURES)															5	5	2					5		5	7
GRAVITATIONAL ANOMALIES						2	10							2			2		5						8
MAGNETIC ANOMALIES				2	2	10	2										2		5		5				9
BOTTOM COMPOSITION						2	5								2		10	2			5			2	10
SURFACE CHARGE	2	2		2		2		2			2		2	2							2	5			14

FOLDOUT FRAME 1

FOLDOUT FRAME 2

Table 4-4
SELECTED KNOWLEDGE REQUIREMENTS (Meteorology)

MEASUREMENT REQUIREMENTS	51 DETERMINE TEMPERATURE FIELD	52 DETERMINE AIR MOTION FIELD (ADVECTION, ACCELERATION)	53 DETERMINE ATMOSPHERE COMPOSITION AND MASS (PRESSURE FIELD)	54 DETERMINE WATER VAPOR DISTRIBUTION	55 DETERMINE OZONE DISTRIBUTION	56 DETERMINE AEROSOL PARTICLES, SOURCES, TYPES AND EXTENT	57 DETERMINE ENERGY EXCHANGE	58 DETERMINE MOMENTUM EXCHANGE	59 DETERMINE DIFFUSION PROPERTIES IN THE ATMOSPHERE	60 DETERMINE EVAPORATION/CONDENSATION DISTRIBUTION	61 DETERMINE RADIATIVE PROPERTIES OF THE ATMOSPHERIC LAYERS & BOUNDARIES	62 DETERMINE HEAT SOURCES & SINKS	63 DETERMINE SPECTRAL DISTRIBUTION OF SOLAR RADIATION	64 DETERMINE GLOBAL HEAT BALANCE	65 DETERMINE THE RADIO PROPAGATION CHARACTERISTICS OF THE ATMOSPHERE	66 DETERMINE ACOUSTIC PROPAGATION CHARACTERISTICS OF THE ATMOSPHERE	67 DETERMINE EXTENT AND TEMPERATURE GRADIENT OF STABLE LAYERS	68 DETERMINE EXTENT OF SMALL SCALE TURBULENCE/CIRCULATION	69 DETERMIN	70 PATTERNS	71 DETERMINE CLOUD TYPE, HEIGHT, THICKNESS AND DENSITY	72 DETERMINE CLOUD MOTION AND LIFE	73 DETERMINE CLOUD DROPLET AND ICE CRYSTAL SIZE DISTRIBUTION	74 DETERMINE PRECIPITATION EXTENT, TYPE, AND INTENSITY	75 DETERMINE POLLUTION SOURCES AND EXTENT	76 LOCATE AND TRACK AIRBORNE OBJECTS	77 LOCATE JET STREAMS	78 LOCATE AREAS OF FOG, ICING AND CAT	79 LOCATE & TRACK SEVERE LOCAL STORMS (THUNDERSTORMS, TORNADOS, DUST, ETC.)	80 LOCATE AND MONITOR LOCAL CIRCULATION	81 LOCATE AND MONITOR HURRICANES	82 LOCATE AND MONITOR FOREST FIRES	83 DETERMINE ICE AND SNOW COVER	84 DETERMINE SURFACE WATER AREAL EXTENT AND STATE	85 LOCATE AND TRACK SURFACE OBJECTS	86 DETERMINE GENERAL CIRCULATION CHANGES	87 DETERMINE CLIMATE CHANGES	88 DETERMINE LAND USE DISTRIBUTION PATTERNS AND SURFACE CHARACTERISTICS	89 MONITOR VOLCANIC ACTIVITY	90 MONITOR LAND EROSION/SEDIMENTATION	91 MONITOR MAN MADE AND NATURAL EXPLOSIONS	92 DETERMINE ATMOSPHERIC CHARACTERISTICS OF OTHER PLANETS	93 DETERMINE ELECTRIC FIELD / MONITOR UPPER ATMOSPHERE PHENOMENA	OCCURRENCE
51 PRESSURE	5	5	10		2	5	5	5				2		5			2		2		2		2			2		2		2					5		2	2		2	2			21
52 TEMPERATURE	10			2			2			5	10	2	5	5	2	2	5		2	5	2		5			2	2				2	5								2	2	2		22
53 EMISSIVITY	10				5							5		5	2				10	0		5	10	2	2	2	10	10	2								5							16
54 WATER VAPOR	10		5	10		5	5		2	10	5		2	5	5				10	5	5	10	10				5	2				2	2			2					2	2		23
55 GAS CONCENTRATION (CO_2 O_3 NO ETC.)	5		10		10		5		2		5	5	5	5		5	2							5	2						2					2		2						16
56 ATOMIC & MOLECULAR CONCENTRATION & EFFECTS			10				5				2		5		5																				2					2	5	2	10	10
57 LIQUID SIZE SHAPE, & CONCENTRATION			5	5		2				10	5		2	2	2			2	10	0	10	10	10				5														5			16
58 ICE SIZE, SHAPE & CONCENTRATION	5		5								2		5	2					5	0	5	10	10	2								10	5								5			14
59 AEROSOL SIZE SHAPE, & CONCENTRATION	2		2			10				5			2				5						5	10								5							5			2			11
60 ELECTRIC CHARGE				2		2				2									5			2	5								2								2				10	2	10
61 ELECTRIC DISCHARGE																			5				5	2				5		2							2	2				10	2	9
62 IONIZATION			2		5		2						5		2									2																2	5	5	5	10
63 MAGNETIC ANOMALY													5		2													2		2												10		5
64 AIR & CLOUD HORIZONTAL MOTION	5	10	5		5	5	2	2	5	5						2			2		10		5		5	2	2	5	5	2	2				5	2	2	2					2	25
65 AIR & CLOUD VERTICAL MOTION	5	10	5		2		2	5	2	5									5		5		10		5	2	2	5	5	2	2						2	2		2			2	23
66 COLOR			2								5													5			2				5	2	5				10	5	10		5			11
67 AIRBORNE OBJECTS - SIZE, SHAPE, AND CONCENTRATION	5	10	5	5	2	2	2	2	5	2	2	2	2				2	2	2		5			5	10	2			2						5							2	2	25
68 DENSITY	5	5	10	5	2											2			2						2				2						5						2			12
69 REFLECTION	2	5								5	10	2	5	5					10	0	5	5	5			2	10			5		10	10			5	10		2					20
70 HEAT FLUX	5			5	2		5			5	10	10	5	5					5				5					2			5	2	5		2		2	5			5		2	20
71 ACOUSTIC SIGNATURE	2			2												10	5	5	2																					5	2		2	10
72 SCATTERING	2	2	5	5	5	10	2	2	5	2	10	2	5	2	2	2	2		5			5		5			2	2						2	2		5	5	2	2	5		2	31
73 RADAR & MICROWAVE SIGNATURES	5	5								5	5							2	5		5	2	10		5	2		10		10		10	5	5			5	2	2		5			21
74 CLOUD PATTERNS	10	5	2	5						10	10	10	5	10		2	2	2	10		5	5	2			5	5	5		10					5	2				5	5	2	5	27
75 CLOUD HEIGHT	2	2		5			5			10	5	10	5	5		2	2	2			5	5	5			2	2	5	2	10											2			22
76 SUN GLINT		10																	5								2						10											5
77 SURFACE ROUGHNESS	2	5	2	5		5	5	5		2				2			2	5	2		2		5	2			2		5			5	5			2	10							22
78 TURBULENCE	5	5					2	2				2					5	5					5			5	10	5		2	2						2			5				16
79 PRECIPITATION				2			2			10		2		2					5		5	10	10	2		2	2	2		2						2								16

FOLDOUT FRAME

FOLDOUT FRAME 2

Section 5

STUDY RESULTS

The ORDS, when taken as a composite set of potential measurements for orbital oceanography and meteorology, provided interesting insights into the general observational patterns which might be anticipated in future research programs. The patterns or trends observed suggest answers to mission-planning questions regarding the spectral regions of importance, the grid-point sampling intervals, the frequency with which the measurements should be made, the role of potential observational platforms, the role of man, orbital operation requirements, and the specific instruments or sensors needed for a comprehensive measurement program.

5.1 SPECTRAL REGIONS OF INTEREST

For a comprehensive measurement program in orbital oceanography and meteorology, the principal spectral regions of interest are the visible (0.4 to 0.8μ), infrared (0.8 to 50μ), and microwave (10^3 to 10^5μ) bands. Spectral-sensing requirements for 31 of the more important measurement areas are summarized in Figures 5-1 and 5-2. For nearly every phenomenon of interest, measurements were required in more than one spectral region. In many cases, multiband sensing was required to provide secondary or "control" data which could be used to aid in interpreting the significance of the data gathered in the spectral region of primary measurement interest. As an example, IR upwelling from the Earth's surface in the 10 to 11μ region is occulted or attenuated by clouds in the field of view. Since the energy detected would be radiated at the cloud's temperature, a control measurement is needed (probably in the visible region) to verify the radiation source.

Because of their three-dimensional nature, meteorological phenomena generally require a greater number of wavelength regions in their measurement programs than do oceanographic phenomena. To illustrate, the differential absorption bands of the various constituents of the Earth's atmosphere are important factors in controlling the amount of the reflected and scattered radiation which could be observed from the vantage point of space. Comparison of the relative amounts of reflected and scattered radiation in various portions of the electromagnetic spectrum provides a feasible technique for assessing such factors as cloud cover; cloud heights; precipitation; surface temperature; and the vertical distribution of temperature, water vapor, CO_2, and ozone. Since the oceanographic measurements feasible from remote platforms are essentially of a two-dimensional nature, it appears that less need exists for broadband coverage. Required oceanographic measurements were found

	ULTRA-VIOLET	VISIBLE 0.4 TO 0.8	NEAR IR 0.8 TO 3μ	MIDDLE IR 3.0 TO 50μ	FAR IR 50 TO 10^3μ	MICROWAVE 10^3 TO 10^5μ
PLANKTON AND FISH		○				○
SURFACE OBJECTS		○				○
CLOUD PATTERNS		○	○	○		●
LOCAL WINDS		○				●
SLICKS	○	●		○		
SEA STATE		○				○
WAVES		●				○
SURF		○				○
SEA SURFACE TEMP.		●		○		●
ICEBERGS		●		○		●
OCEAN CURRENTS		●	○	○		○
POLLUTION		○ ●	○	○	○	●
COASTAL FEATURES		○				●
ANOMALIES						
BOTTOM COMPOSITION		○				
AIR SEA INTERFACE		○	○	○		○

LEGEND ○ PRIMARY ● CONTROL

Figure 5-1. Space Sensing Spectral Requirements-Oceanography

	ULTRA VIOLET	VISIBLE 0.4 TO 0.8μ	NEAR IR 0.8 TO 3μ	MIDDLE IR 3 TO 50μ	FAR IR 50 TO 10^3μ	MICROWAVE 10^3 TO 10^5μ
SURFACE TEMPERATURE		●		○		○
VERTICAL TEMP. PROFILE		●		○		○
SURFACE WINDS		○				○
VERTICAL WINDS PROFILE		●		○		○
SURFACE MOISTURE		●		○		○
VERT. WATER VAPOR PROFILE		●		○		○
CLOUD COVER		○ ●	○	○		
CLOUD TOP HEIGHT		○ ●	○	○		
PRESSURE		○	○			○
SEVERE STORMS		○ ●	○	○		○
PRECIPITATION						○
HEAT BUDGET	○	○ ●	○	○	○	○
AIR POLLUTION		○ ●	○	○		○
CLEAR AIR TURBULENCE		●		○		○
SNOW, ICE COVER		○ ●	○	○		○

Figure 5-2. Space Sensing Spectral Requirements-Meteorology

to lie primarily in just two regions, the visible and microwave. Color photography would provide directly usable data on the dynamics of ocean waters, plankton content, ice coverage, cloud coverage, sea state, and many other phenomena. Microwave measurements of surface temperature gradients are preferred over the IR, since they are not appreciably affected by clouds or atmospheric water vapor. Considerable research and ground truth testing is required, however, before the feasibility of microwave systems can be established.

5.2 SPATIAL RESOLUTION (GRID-POINT SAMPLING)

For each of the items identified in the study, the required distance between discrete measurements (grid-point sampling) was determined. This spatial resolution should not be confused with the resolution of the parameter in terms of accuracy and precision of the measurement. Rather, it is the sampling distance or spatial variability of the phenomena of interest. A comparison of the data plotted in Figures 5-3 and 5-4 suggests that oceanographic phenomena require measurements made at closer spatial intervals than meteorological phenomena.

5.3 TEMPORAL RESOLUTION (SAMPLING FREQUENCY)

Observation or data-sampling frequency (Figures 5-5 and 5-6), i.e., the interval of elapsed time subsequent measurements of each parameter at the same grid point, was also examined. Measurement of meteorological parameters required sampling at more frequent time intervals than oceanographic parameters. In Figures 5-5 and 5-6, a horizontal line delineates the range of observation frequencies required for each parameter. The horizontal lines reflect the range of sampling rates from "desired" through "usable." It should be noted that the span of observation-frequency requirements for plankton and fish varies from hourly to monthly data. The extended range associated with biological parameters results from the study of marine life and its ecology, in which life cycles which vary from hours to decades are observed.

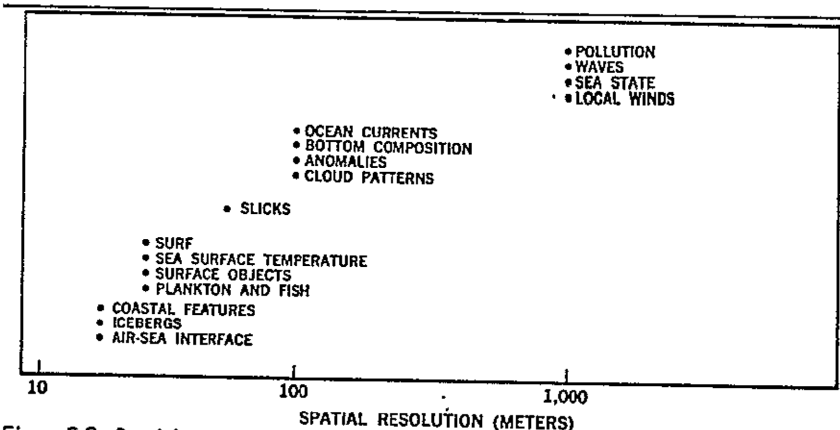

Figure 5-3. Spatial Resolution Requirements-Oceanography

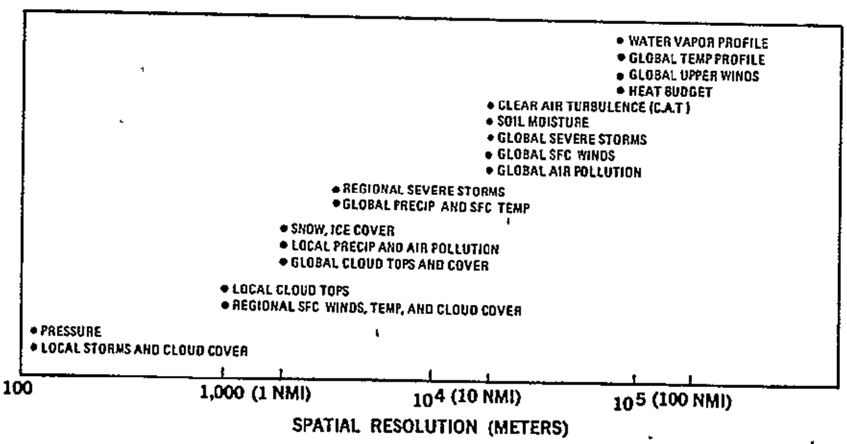

Figure 5-4. Spatial Resolution Requirements-Meteorology

5.4 OBSERVATIONAL PLATFORMS

The information contained in Figures 5-3, 5-4, 5-5, and 5-6 are cross plotted in Figure 5-7. While similar regions of the spectrum are of interest to oceanographers and meteorologists (Figures 5-1 and 5-2), the observation programs are quite different. The oceanographic events change more slowly than meteorological phenomena but require finer grid-point sampling intervals. Requirements for synoptic and continued coverage of

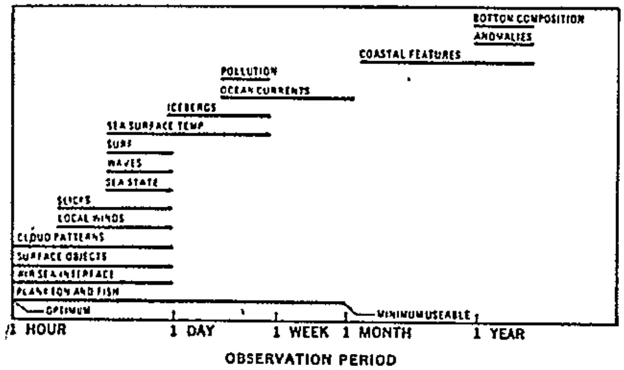

Figure 5-5. Observation Frequency Requirements-Oceanography

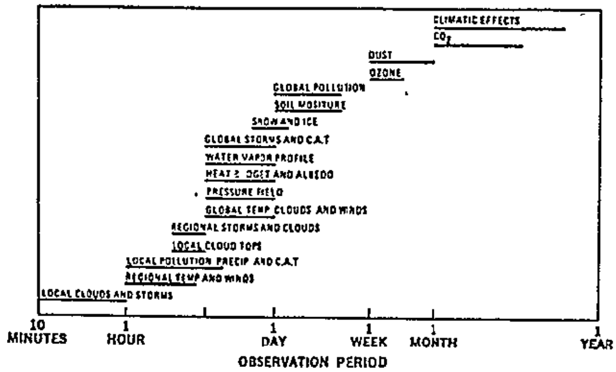

Figure 5-6. Observation Frequency Requirements-Meteorology

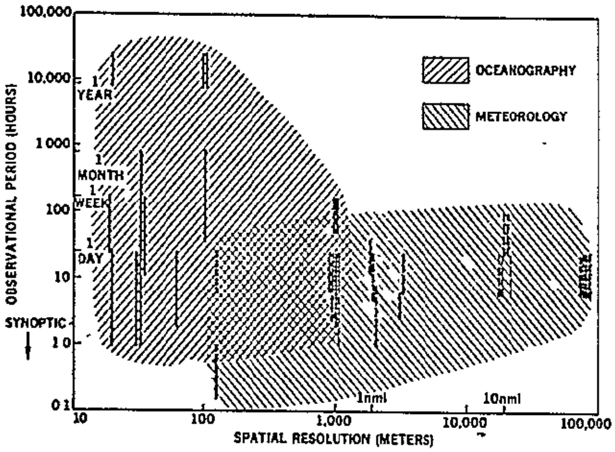

Figure 5-7. O&M Data Requirements Summary-A

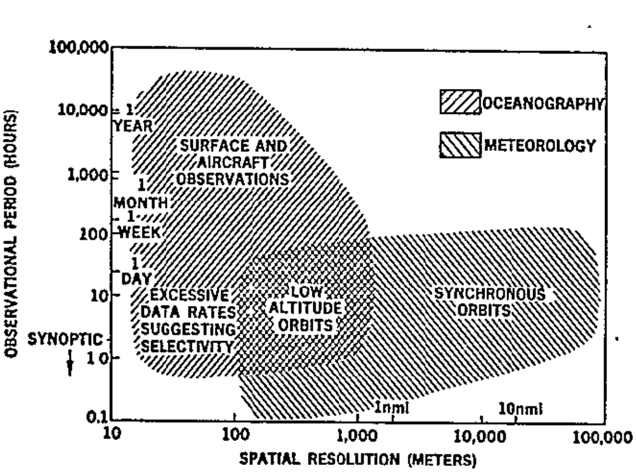

Figure 5-8. O&M Data Requirements Summary-B

meteorological events require data gathering on an hourly to daily basis as contrasted to oceanographic measurements which require daily to yearly sampling intervals.

These observational patterns suggest that different orbital platforms may be required (Figure 5-8). The relatively coarse measurements requiring frequent observations, typical of certain global weather events, would be adequately accommodated by vehicles in synchronous orbits. The very slowly changing oceanographic phenomena requiring relatively fine spatial resolution would be adequately accommodated by surface and aircraft observations. The oceanographic and meteorological measurements made frequently with fine spatial resolution might be obtained by satellite in low-altitude orbits.

The program defined included two major measurement elements: an R&D phase and an operational phase (Figure 5-9). The development of instruments, measurement techniques, and operational theories or models are the R&D objectives. The operational systems involve the more routine data gathering, processing, and dissemination. As descriptive and predictive techniques are developed in the R&D phase, they in turn establish the sensors, data processors, and information interfaces needed in the operational system by the using agencies.

The shifting pattern of demands for measurement platforms was examined for the R&D (Figure 5-10) and the operational phases (Figure 5-11). Orbital facilities, aircraft, surface vehicles, and multiple combinations, including orbital platforms, were considered. Criteria used in identifying the most responsive type of measurement platform were (1) projected equipment development status and space flight worthiness of instruments; (2) necessity for concurrent measurements, such as ground-truth verification; (3) the required geographical coverage and resolution; and (4) the periodicity, frequency, and duration of the observations.

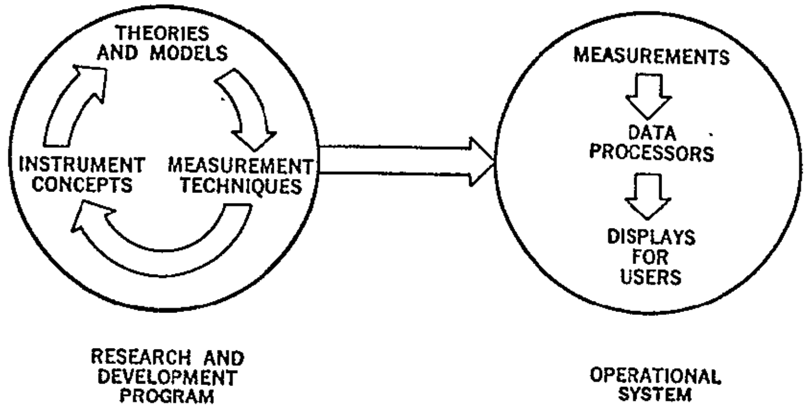

Figure 5-9. Technical Objective Achievement

Most orbital measurements identified for the R&D phase required ancillary verification or "ground truth" testing. Certain theoretical studies, however, could be verified by specific experiments performed on the orbital platform. These generally relied on some unique advantages of orbital space (zero-g, synoptic coverage capability, etc.). An example is the zero-g required in various experiments dealing with cloud physics and weather modification mechanisms.

Some measurements were identified by the scientific contributors as being of potentially great value if they could be made on a synoptic basis, even though no feasible technique was currently available for remote sensing. These types of measurements were included in the analysis for completeness but were identified as being feasible only from surface vessels. Examples are sea-surface electric charge and gravitational and magnetic anomalies.

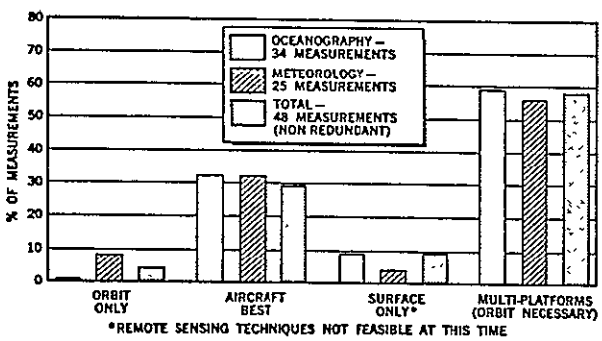

Figure 5-10. Measurement Platforms-Research and Development Phase

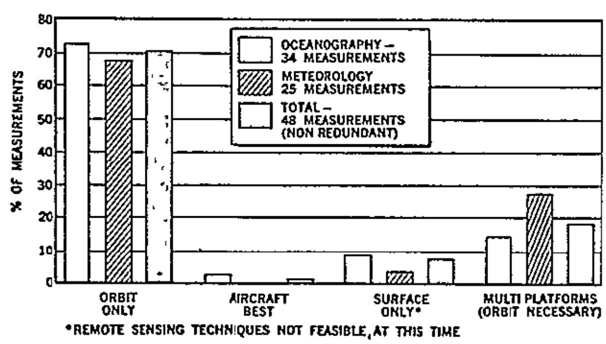

Figure 5-11. Measurement Platforms-Research and Operational Phase

As the emphasis on the measurement programs shifts towards the operational systems, the use of independent orbital facilities becomes more important (Figure 5-11). However, aircraft appear to continue to offer advantages in those operational areas dealing with the assessment of such slowly changing phenomena as coastline patterns and bottom anomalies. These trends are based solely on the expected ability of the given platform to satisfactorily accomplish the observations. The comparative operating economies of the various platforms were not considered in this study.

5.5 THE ROLE OF MAN

Although an evaluation of the role of man in orbital operations involves analysis beyond the scope of the present study, the data at hand permitted at least a preliminary assessment of his potential contribution. The rationale followed in this analysis acknowledged that man could be "engineered" out of the orbital system but usually at the price of increased complexity, decreased reliability, and decreased system capability. On the other hand, man requires complex support equipment and is therefore costly. Each measurement requirement was analyzed to determine the nature of man's possible contributions to the program and how they might change the R&D and the operational phase. Five potential contributions of man were identified:

1. Selection of targets.
2. Checking of complex instrument functioning.
3. Calibration and testing of new and complex instruments.
4. Manipulation of observation meterials.
5. Visual observations.

Each measurement was weighed against these criteria; man was considered "valuable" in space if three or more were involved in the measurement program and "useful" if one or two were satisfied (Figures 5-12 and 5-13). Results indicated that man could make a useful or valuable contribution to nearly 50% of the measurement programs in the R&D phase. In the operational phase, however, the role of man became less certain, as indicated by the significant number of "to-be-determined" judgments. The measurement programs requiring man were generally those involving highly complex instruments with selective pointing, or specific zero-g experiments requiring monitoring and controlling.

It should be noted that this analysis did not represent an exhaustive evaluation of the role of man. Other potential uses of man which capitalize on his natural ability, training, and specific skills as a scientist, observer, and operator, as well as those functions attendant to the maintenance of the spacecraft and its payload, require further study.

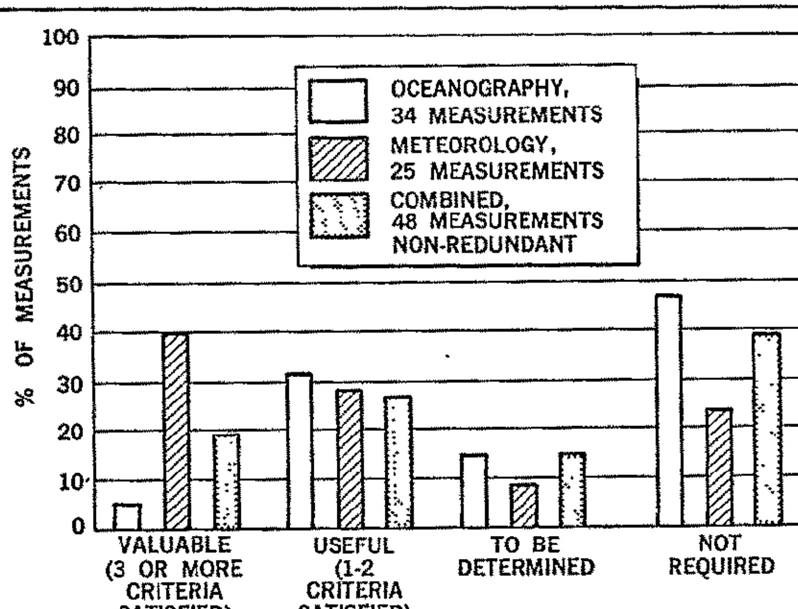

Figure 5-12. Manned Orbital Requirements-Research and Development Phase

5.6 ORBITAL OPERATION REQUIREMENTS

Analyses of orbital inclinations for various

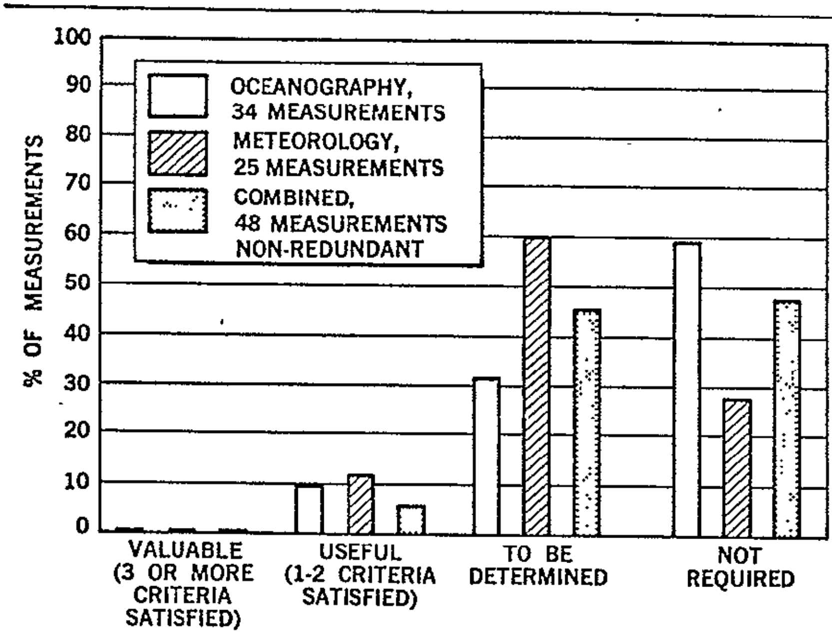

Figure 5-13. Manned Orbital Requirements-Operational Phase

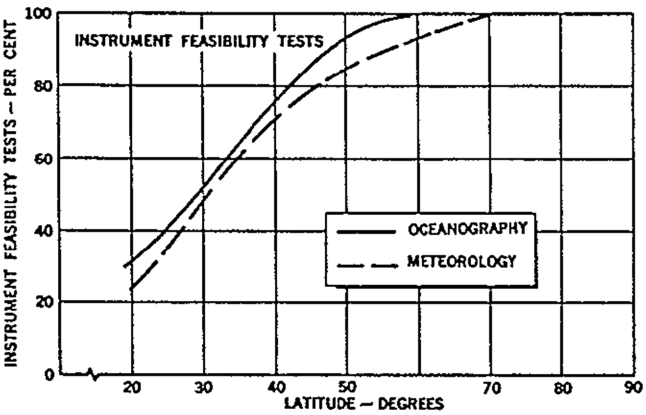

Figure 5-14. Latitude Requirements-Research and Development

R&D and operational activities (Figure 5-14) indicated that 50% of oceanography and meteorology instrument feasibility tests could be accomplished between 0° and 30° north and south latitude and all could be accomplished in a 70° orbit inclination. Figures 5-15 and 5-16 show the latitude coverage providing various degrees of measurement capability for short-range, extended-range and long-range prediction for two regions: the tropics and the mid-latitudes. Data requirements for both vary, but they are clearly a function of the length of time of the forecast period. When longer range forecasts are desired, higher latitude data is needed in the predictive model.

5.7 INSTRUMENT REQUIREMENTS

Examination of instruments required for the various measurement programs indicated that 25 generic classes would provide the basic data needed in the R&D phase of the program development activity.

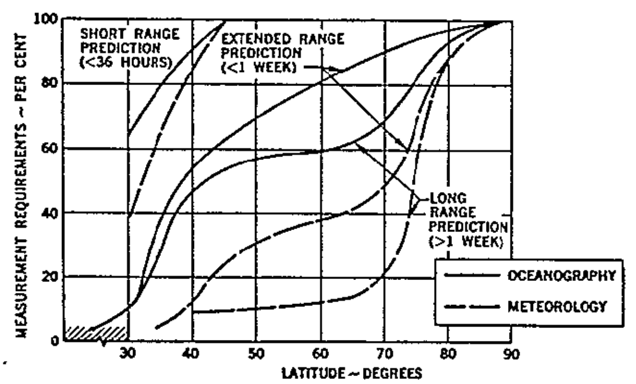

Figure 5-15. Latitude Required for Operational Requirements-Tropic Regions

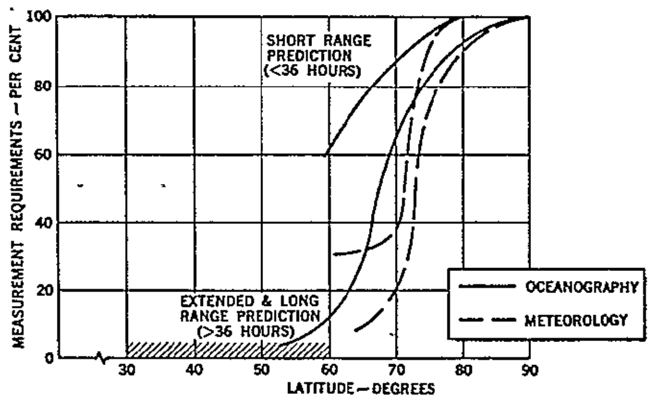

Figure 5-16. Latitude Required for Operational Requirements-Midlatitude Regions

Currently available or proposed instruments were examined to determine whether they provided the desired instrument capabilities and the measurement requirements. The prime source of data on existing and proposed instruments was the NASA-supplied lists from the Nimbus and Applications Technology Satellite programs and from the APS A and B Apollo Applications Program. Of the 25 required instruments, 20 could be identified in current or proposed NASA programs; 5 were new. Figure 5-17 summarizes the types and program sources for these instruments.

Instruments proposed for APS A and B programs would play a significant role in satisfying the oceanography and meteorology program requirements. If these programs did not materialize, a corresponding gap in equipment development would exist.

Section 6

SCOPE OF STUDY AND STUDY LIMITATIONS

The foregoing discussion has described the procedures followed in identifying orbital-research objectives in a logical and systematic manner. The study has examined the disciplines of oceanography and meteorology from the viewpoints of the research scientists and of other potential users of the information. Recommendations for specific classes of measurements have been made.

The study was limited to the examination of the oceans, the atmosphere, and their interaction. Coastal zones were included, but the freshwater or limnological zones were not. Also, the tidal influence of the sun and the moon on the atmosphere was not explored. Before a comprehensive plan for Earth-oriented research can be developed, these and other regions of Earth-centered observations should be analyzed. It can be anticipated that agricultural and forestry applications, geological surveys, and photogrammetric mapping activities would require many of the same types of sensing devices in orbit as found useful for oceanography and meteorology. Establishing the measurement commonalities among a multidisciplinary set of research objectives would undoubtedly suggest more efficient and effective orbital-research program plans.

Once a multidisciplinary orbital-research or experiment plan has been formulated, the remaining steps in the overall program planning can be accomplished: supporting R&D can be

INSTRUMENTS REQUIRED	CURRENT PROGRAMS				ADDITIONAL REQUIREMENTS
	EXISTING		EXTENSIONS		
	NIMBUS	ATS	APS A	APS B	
INTERROGATION RECORDING AND LOCATING SYSTEM (IRLS)					
HIGH RESOLUTION INFRARED RADIOMETER (HRIR)					
UHF STERICS RECEIVER					
MEDIUM RESOLUTION IR RADIOMETER (MRR)					
MICROWAVE RADIOMETER (MWR)					
INFRARED INTERFEROMETER SPECTROMETER (IRIS)					
DAY-NIGHT CAMERA (DNCS)					
ADVANCE VIDICON CAMERA SYSTEM (AVCS)					
SPIN SCAN CAMERA SYSTEM (SSCS)					
SYNOPTIC MULTIBAND CAMERA					
WATER VAPOR MICROWAVE SPECTROMETER					
STAR TRACKER					
12 INCH F.L. METRIC CAMERA					
24 INCH F.L. HIGH RESOLUTION CAMERA					
PASSIVE MICROWAVE STEREO IMAGER					
8 GHZ RADAR ALTIMETER/SCATTEROMETER					
HIGH RESOLUTION RADAR IMAGER					
SCANNING UV VIS. IR ABSORPTION SPECT					
GRAVITY GRADIOMETER					
MAGNETOMETER					
LANGMUIR PROBE					
ULTRAVIOLET PHOTOMETER					
PYRHELIOMETER					
PULSED LASER					
POLARIMETER					

OCEANOGRAPHY METEOROLOGY

Figure 5-17. O&M Instrument Package Accommodation

identified; design requirements for space laboratories and facilities can be specified; and the mission operations and ground support necessary can be defined. Hardware development times and costs will then provide a basis for the preparation of a realistic time-phased program plan. These steps remain to be taken.

The present study was further limited to the identification of observational requirements which were of value to oceanographic and meteorological research and which appeared to be potentially feasible from remote platforms. No attempt was made to assess the economic tradeoffs involved in determining the cost effectiveness of the various potential data-gathering platforms, (i. e., aircraft, surface vessels, or orbital facilities) although judgments were made regarding the most responsive type of measurement platform from an engineering or research standpoint.

Finally, the scheduling of orbital research requires an ordering of research objectives. This implies the assessment of priorities for the measurements as a function of the relative importance of the critical issues to which the measurements are directed. During the present study, the scientific contributors were asked for their judgments regarding the relative importance of the issues identified. There was generally universal agreement that both atmospheric and oceanographic pollution were the most important issues. Beyond this point, judgments differed. While it was beyond the scope of the present study to pursue the problem of priority assessment with the scientific community as a whole, it must be recognized that, unless a consensus can be derived by competent authority, future planning studies will be limited in their ability to establish the most significant and effective experiment plan.

Section 7

IMPLICATIONS FOR RESEARCH

The Oceanography and Meteorology Study found that a significant number of the measurements necessary to fulfill the study objectives can be implemented by a remote-observation program. For remote sensing of certain parameters, such as surface charge, bottom composition, and acoustic signature, an advance in technology is needed. The importance of these variables suggests that research might profitably be directed toward these areas.

Besides the instruments to implement the measurements program, other factors are required to completely synthesize the system. For example, one major objective of the meteorology program is the achievement of accurate, long-range weather forecasts. While capabilities exist today for 36-hour forecasts based upon simplified two-degree-of-freedom models with 500-km resolution, accurate 10- to 14-day forecasts require more complicated three-degree-of-freedom models; with input data accurate to a 5-km resolution level (Figure 7-1).

Development of more accurate long-range forecasting requires sensors capable of much finer resolution and requires more frequently sampled observations of the atmosphere. Coupled with these trends are requirements for advanced mathematical models capable of operating with increased fidelity in simulating the physical situation. Study of recent COSPAR reports indicates that major portions of the numerical models necessary in the simulation have been formulated but remain to be tested and verified. The refinement and validation of such mathematical models will be a continuing research need.

The trend in meteorology toward higher resolution and more frequent measurements and the advanced theoretical numerical models for weather forecasting makes an advance in computational facilities a more critical requirement. Analysis of these requirements indicates that, to achieve the desired automatic forecasting capability,

an increase of many orders of magnitude in data-processing capacity over currently available systems will be required. Thus, data handling is a major and critical R&D area.

One measure of this, as shown in Figure 7-2, is an increase of 100 million over the requirement for computer operations per unit time found in current system capabilities. This increase represents the increased data-processing load in moving from the short-range forecasts with 500-km grid point resolution currently programmed, to the future requirement for long-range forecasts with 5-km resolution.

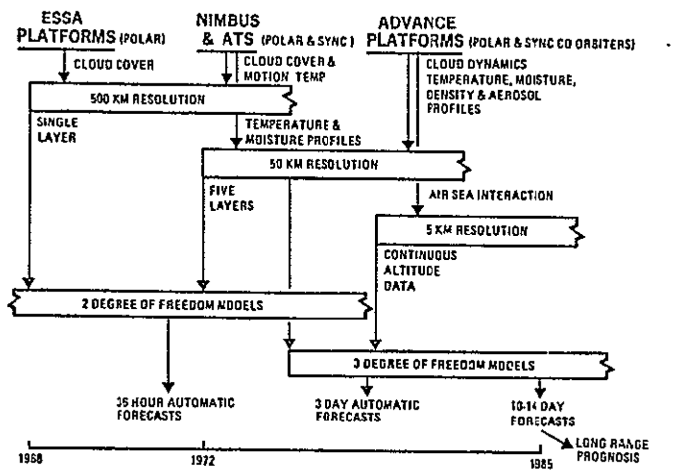

Figure 7-1. Meteorological System Evolution

Similar trends are found in oceanography. Analysis has shown that, for large-scale fisheries prediction and the generation of use-oriented information, the data-acquisition rate exceeds the stated capabilities of any current or contemplated observation platform. As mentioned previously, more fundamental to the problem of implementing a fisheries-prediction system is the formulation and verification of theoretical models of marine biological behavior. Expansion of applied-research activities can validate existing models and develop new ones, as required. These classes of research are very long range programs which can lead to vast increases in scientific understanding of very complex natural processes.

This study did not consider the economic implications of the research program necessary to fulfill the objectives identified by the systematic approach. It should also be noted that no current satellites in orbit directly support oceanography research objectives, although much of the meteorological data currently being gathered can be used in oceanographic research.

An example of the anticipated experiment program evolution foreseen for orbital oceanography and meteorology is documented in Volume II, Appendix A. Certain characteristics can be seen in the total measurement requirements, which provide insight into the expected role of a manned space platform during the early research phase. Towards this end, measurement requirements were suggested for areas (1) where manned participation is valuable or useful and (2) where orbital platforms or a combination of space and other platforms is needed. This subset of total requirements includes such observation types as sea color, turbidity, and bioluminescence; storm tracking, air, and cloud motion; sea-surface temperature; surface, and airborne objects; vertical soundings of temperature, pressures, moisture, and winds; gaseous, liquid and solid composition of the atmosphere; and electrical discharges.

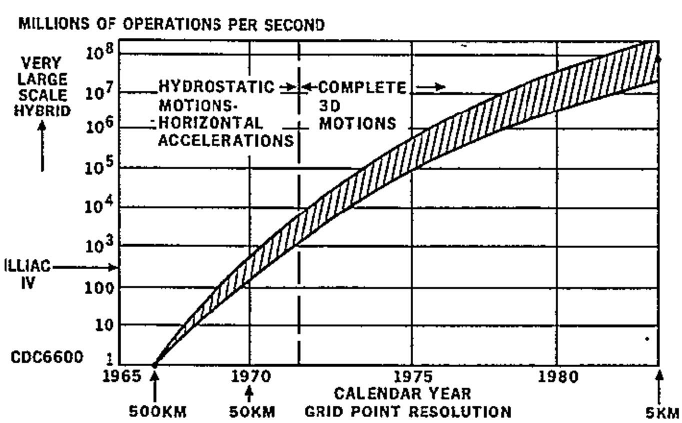

Figure 7-2. Computer Requirements for Automatic Weather Prediction

Study of the instrument-development requirements has indicated that initial

emphasis can most profitably be placed on the development of cameras and IR radiometers. These, in turn, are followed by spectrometers, microwave radiometers, radars, and groups of these instruments functioning together. Nighttime coverage becomes practical as radiometers and low-light-level camera systems are introduced. Spectrometers permit temperature- and moisture-profile observations, while microwave radiometers and radars allow sensing of surface and rainfall conditions.

The measuring instruments finally used in orbital research will include the more advanced and complex sensors of the equipment grouping. Also, the functional activities involved in performing these measurements can be anticipated to be particularly complicated during the early research phase, considering requirements for simultaneously making observations and ground truth tests. Man's role as a researcher, observer, and instrument operator during this critical early research phase will be particularly important. His natural ability, coupled with training and specific skills, will address such orbital activities as critical instrument adjustments, coordinated experimental procedures where several parties will be in voice contact with each other, on-board handling of important data, observational techniques, and early interpretation of results of individual research experiments. When these scientific duties are coupled with other required on-board supporting activities, such as maintenance and repair, the synergistic observational capability of a flexible manned orbital-research facility will be fully realized.

Section 8

SUGGESTED ADDITIONAL EFFORT

This study explored the areas of oceanography and meteorology research and identified elements of a long-range experiment plan which would profit by the use of space platforms, utilizing the capability provided by manned operations. In doing so, this study has examined a significant portion of the sun-Earth coupled system. To identify completely all sun-Earth interactions and relationships, however, the study should be expanded to cover other related areas of interest such as the limnological zone (including land, rivers, lakes, and streams) and lithospheric phenomena. From this extended base, the total Earth-oriented program of oceanographic and meteorological research could be synthesized with balanced requirements, mission loads, and specific R&D goals.

In addition to a completed study of the land-sea-air interface, the following areas for further activity are recommended:

1. Expansion of the systematic approach for the identification of research objectives to include other Earth-oriented research areas: agriculture, forestry, geography, geology, and hydrology.
2. Delineation of general mission-planning requirements, promising options, and measurement tradeoffs.
   - A. Identification of major factors influencing operation and configuration design.
   - B. Examination of data-handling needs and system impact on ground facilities.
   - C. Description of mission mode alternatives, day/night observation targeting, and unique research-oriented observational opportunities.
   - D. Determination of economic tradeoffs between alternative data collection methods.
3. Development of a time-phased plan, including engineering estimates of costs and schedules, showing program alternatives, major R&D milestones, and design-decision points.

4. Development of a theoretical base through observation of remotely sensed data which can be used to infer parameters of specific interest to users.
5. Identification of critical R&D areas.

   A. Examination of the needs for key theoretical studies and long-term investigations necessary for model development.
   B. Definition of the pacing experiments requiring zero-g or orbital observations and investigations of technological advance necessary to implement the ultimate data-management requirements.

In summary, the Oceanography and Meteorology Study has been an exploratory effort to define systematically those orbital measurement requirements which would most directly serve the needs of the scientific community and potential using agencies. The design and operation of manned and unmanned space vehicles appears to be well within current technology. To be effectively utilized, however, such vehicles must be responsive to user needs. It is hoped that the effort described in these documents will help provide some insight into an analytic approach which translates user objectives into measurement plans.

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